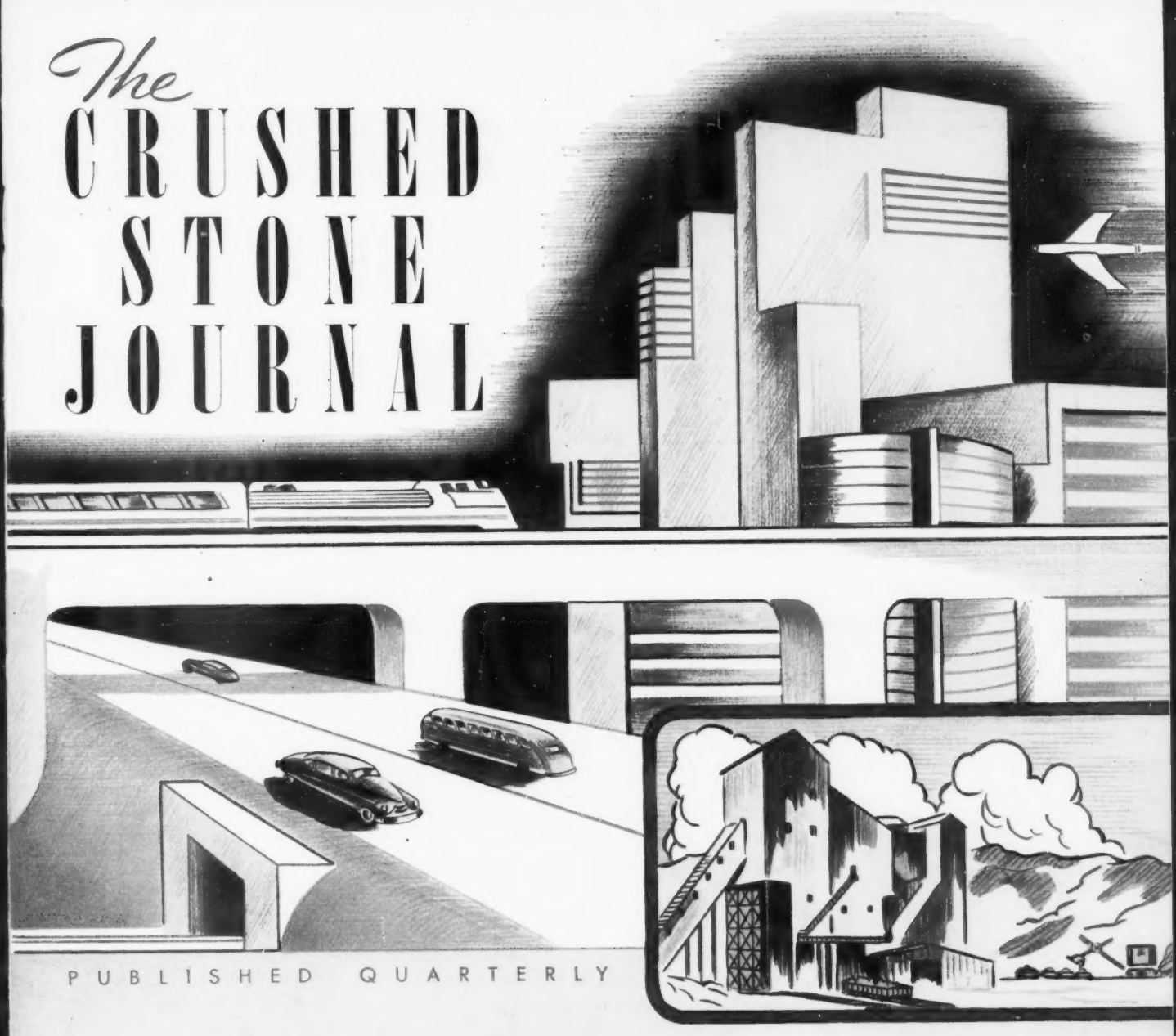
The CRUSHED STONE JOURNAL



PUBLISHED QUARTERLY

In This Issue

March 1956

- 39th Annual Convention
- An Appreciation to Albert T. Goldbeck
- The Past Thirty Years
- Plant Control of Bituminous Concrete Mixes
- Designing Flexible Pavements for Strength – Not Thickness

OFFICIAL PUBLICATION · NATIONAL CRUSHED STONE ASSOCIATION

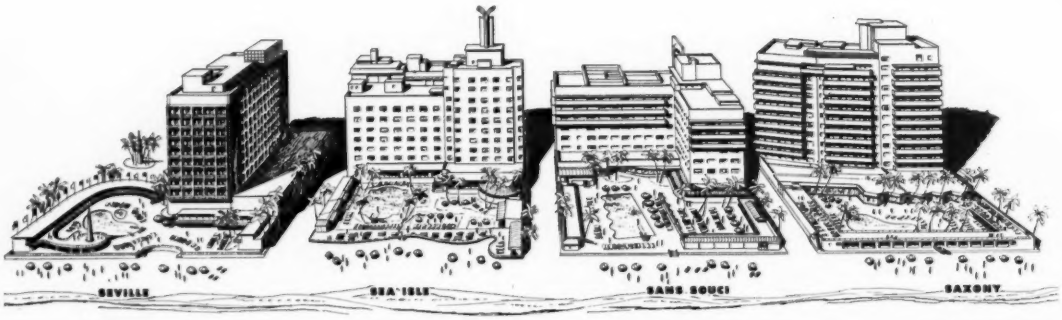
40th Annual Convention

NATIONAL CRUSHED STONE ASSOCIATION

WEEK OF JANUARY 13, 1957

THE *4 MOST* CONVENTION HOTEL GROUP

MIAMI BEACH, FLORIDA



SEVILLE SEA ISLE SANS SOUCI SAXONY

Side by Side on the Atlantic Ocean

Make Plans Now to Attend

The Crushed Stone Journal

Official Publication of the NATIONAL CRUSHED STONE ASSOCIATION

J. R. BOYD, Editor

NATIONAL CRUSHED STONE ASSOCIATION

1415 Elliot Place, N. W.
Washington 7, D. C.

OFFICERS

N. E. KELB, President
JAMES SAVAGE, Treasurer
J. R. BOYD, Administrative Director
A. T. GOLDBECK, Engineering Director
J. E. GRAY, Field Engineer

REGIONAL VICE PRESIDENTS

O. E. BENSON — R. G. L. HARSTONE
A. J. CAYIA — A. W. McTHENIA
H. A. CLARK — W. C. ROWE
H. CLINTON — N. SEVERINGHAUS
B. G. WOOLPERT

EXECUTIVE COMMITTEE

N. E. KELB, Chairman
O. E. BENSON — G. D. LOTT, JR.
T. C. COOKE — A. W. McTHENIA
W. P. FOSS, III — J. V. OWENS
WAYNE W. KING — RUSSELL RAREY
W. C. ROWE

Contents

Page

39th Annual Convention 3

An Appreciation to Albert T. Goldbeck 14

The Past Thirty Years
By A. T. Goldbeck 15

Plant Control of Bituminous Concrete Mixes
By Donald D. Dagler 20

Designing Flexible Pavements for Strength – Not Thickness
By Raymond C. Herner 28

Manufacturers Division Directory 33

N. E. KELB

President
Cumberland Quarries, Inc.
Indianapolis, Indiana

●

Elected President

NATIONAL CRUSHED STONE ASSOCIATION

by the Board of Directors
Chicago, Illinois

February 19, 1956

WAYNE W. KING

W. S. Tyler Company
Baltimore, Maryland

●

Elected Chairman

MANUFACTURERS DIVISION

at its Annual Meeting
Chicago, Illinois

February 21, 1956

THE CRUSHED STONE JOURNAL

WASHINGTON, D. C.

Vol. XXXI No. 1 PUBLISHED QUARTERLY MARCH 1956

39th Annual Convention and Exposition Proves Outstanding

Attendance Records Set in Chicago

N. E. Kelb Elected President – Wayne W. King Heads Manufacturers

A RECORD number of delegates and guests gathered at the Conrad Hilton in Chicago on February 20, 21, and 22, 1956, to help make the 39th Annual Convention of the National Crushed Stone Association one of the most successful meetings in its history.

The increased interest in NCSA and in Association activities was evidenced in the official Convention registration which reached a new high of 1,751. This exceeds, by some 230 persons, the previous attendance record set in 1954. The Convention Arrangements Committee under A. L. Worthen, the Manufacturers Division Exposition Committee headed by B. R. Maloney, and the Operating Session Committee, G. D. Lott, Jr., Chairman, are due a vote of appreciation for their efforts in planning such a successful Convention and Exposition program.

Annual Banquet, National Crushed Stone Association, Conrad Hilton Hotel, Chicago, Ill., February 22, 1956

N. E. KELB
Cumberland Quarries, Inc.
Indianapolis, Ind.
President
National Crushed Stone Association

T. C. COOKE
Lynn Sand and Stone Co.
Swampscott, Mass.
Immediate Past President

RUSSELL RAREY
Marble Cliff Quarries Co., Columbus, Ohio
Elected Past President

EXECUTIVE COMMITTEE

of the

NATIONAL CRUSHED STONE ASSOCIATION

for the year 1956

O. E. BENSON
General Crushed Stone Co.
Easton, Pa.

W. P. FOSS, III
New York Trap Rock Corp.
New York, N. Y.

WAYNE W. KING
W. S. Tyler Co.
Baltimore, Md.
Chairman Manufacturers Division

G. D. LOTT, JR.
Palmetto Quarries Co.
Columbia, S. C.

A. W. MCTHENIA
Acme Limestone Co.
Fort Spring, W. Va.

J. V. OWENS
Eastern Rock Products, Inc., Utica, N. Y.

W. C. ROWE
Rowe Contracting Co.
Malden, Mass.

From Monday morning through Wednesday evening, each day's activities moved rapidly along with interest and participation at a high level. The general sessions offered many subjects of practical value, and in order that everyone may benefit from the full text several of the papers presented at the Convention are reproduced in this issue of the Journal.

The special session for operating men again proved to be a major attraction. One of the largest audiences ever to attend any NCSA Convention session was in attendance. The wealth of information contained in the five subjects, so competently delivered by industry members, will soon be made available in printed form.

Norman E. Kelb Elected President of NCSA

The Board of Directors of NCSA, elected by mail ballot prior to the Convention, held its organizing meeting on Sunday afternoon, February 19, 1956, and as provided in the By-Laws, proceeded to elect the President, Executive Committee, additional Directors, and other officers.

The honor of becoming President of the National Crushed Stone Association for 1956 was unanimously accorded to Norman E. Kelb, President of Cumberland Quarries, Inc., Indianapolis, Indiana. A man who has long given of his time and talents to NCSA, Mr. Kelb was first elected to the NCSA Board in 1935. He became a Regional Vice President in 1936 and a member of the Executive Committee in 1938, serving in these capacities through 1940. During the next few years Mr. Kelb did not serve on the Board because of a change in the status of his company. In 1946 he returned to the Board where he has served to date.

In accepting the presidency, Mr. Kelb expressed his deep appreciation to the Board for the honor bestowed upon him, and said he would, to the best of his ability, effectively continue the outstanding work of his predecessors in building and strengthening the National Crushed Stone Association.

After a statement of commendation, the Board gave a rising vote of appreciation to retiring President T. C. Cooke for the excellent manner in which he had discharged his responsibilities during his two-year term. Mr. Cooke thanked the Board for its loyalty and cooperation during his administration, and pledged his assistance to incoming President Kelb.

Election of Executive Committee and Directors

The next order of business was the selection of the six elected members of the Executive Committee. The names of eleven candidates were placed in nomination and, by secret ballot, the six receiving the highest number of votes were declared elected. These were: O. E. Benson, W. P. Foss, III, G. D. Lott, Jr., A. W. McThenia, J. V. Owens, and W. C. Rowe.

From the category of voting Past Presidents, Russell Rarey was a unanimous choice for re-election to the Executive Committee.

Meeting of Newly Elected NCSA Board of Directors

NEWLY ELECTED TO NCSA BOARD

HAROLD BIEHN
Blue Rock, Inc.
Washington C. H., Ohio

ABNEY BOXLEY
Blue Ridge Stone Corp.
Roanoke, Va.

CHARLES COBURN
Waukesha Lime & Stone Co., Inc.
Waukesha, Wis.

P. V. COREY
Blue Rock Quarry
Cumberland Mills, Maine

ALFRED N. FOLEY
West Roxbury Crushed Stone Co.
West Roxbury, Mass.

JAMES H. GROVE
M. J. Grove Lime Co.
Frederick, Md.

JAMES L. HOLDEN
Genesee Stone Products Corp.
Batavia, N. Y.

Also serving on the Executive Committee in an ex officio capacity will be the President and Immediate Past President of NCSA, and the Chairman of the Manufacturers Division. The full personnel of the Executive Committee for 1956 is as follows:

EXECUTIVE COMMITTEE

Norman E. Kelb, Cumberland Quarries, Inc., Indianapolis, Ind., *Chairman*
O. E. Benson, General Crushed Stone Co., Easton, Pa.
T. C. Cooke, Lynn Sand & Stone Co., Swampscott, Mass.
W. P. Foss, III, New York Trap Rock Corp., New York, N. Y.
Wayne W. King, W. S. Tyler Co., Baltimore, Md.
G. D. Lott, Jr., Palmetto Quarries Co., Columbia, S. C.
A. W. McThenia, Acme Limestone Co., Fort Spring, W. Va.
J. V. Owens, Eastern Rock Products, Inc., Utica, N. Y.
Russell Rarey, Marble Cliff Quarries Co., Columbus, Ohio
W. C. Rowe, Rowe Contracting Co., Malden, Mass.

The Board also exercised its option, as provided in the By-Laws, of electing two Directors-at-Large from the active membership. Philip V. Corey, President, Blue Rock Quarry, Cumberland Mills, Maine, and James H. Grove, Jr., Treasurer, M. J. Grove Lime Company, Frederick, Maryland, were unanimous choices.

In a separate action, Miss Margaret McD. Smith, Secretary-Treasurer, Central Rock Company, Lexington, Kentucky, was elected to fill a vacancy occurring since the Board election by mail ballot.

Five new members of the Board, elected by mail ballot prior to this meeting, were extended a cordial welcome when introduced by President Cooke. The new Board members are:

Harold Biehn, Blue Rock, Inc., Washington Court House, Ohio
Abney Boxley, Blue Ridge Stone Corp., Roanoke, Va.
Charles Coburn, Waukesha Lime & Stone Co., Inc., Waukesha, Wis.
Alfred N. Foley, West Roxbury Crushed Stone Co., West Roxbury, Mass.
James L. Holden, Genesee Stone Products Corp., Batavia, N. Y.

Other Elections

H. E. Rodes, Nashville, Tennessee, Stirling Tomkins, New York, New York, and Harold Williams, Boston, Massachusetts, were unanimously re-elected

as Honorary Members of the Board. An addition to this very select group was O. M. Stull, President, Liberty Limestone Corporation, Buchanan, Virginia, who had resigned from active membership on the Board during the past year. In its unanimous election of Mr. Stull, the Board recognized his long and active interest in NCSA, and his many valuable contributions as a past Board member.

JAMES SAVAGE
Buffalo Crushed Stone Corp., Buffalo, N. Y.
Re-elected Treasurer

The following Association officers were also unanimously re-elected: James Savage, Treasurer; A. T. Goldbeck, Engineering Director; J. R. Boyd, Administrative Director and Secretary, and J. E. Gray, Field Engineer.

A mail ballot election, conducted prior to this meeting of the Board, resulted in the election of the nine Regional Vice Presidents of NCSA. The pictures of each Regional Vice President, together with the area designated for each Region, will be found on page 8 of this issue of the Journal. Making first appearances as Regional Vice Presidents are O. E. Benson, Eastern Region and Nelson Severinghaus, Southeastern Region.

Ladies Also Set Attendance Mark

A most gratifying development of the 1956 Convention was the splendid turnout of 118 ladies who were quick to voice approval of the special program planned for their entertainment. The success of this part of the Convention activity was enhanced greatly

Hostesses for Ladies Entertainment
Left to Right: MRS. RUSSELL RAREY, MRS. T. C. COOKE, MRS. M. E. MCLEAN, MRS. HOUSTON CLINTON

by four gracious and charming hostesses—Mrs. T. C. Cooke, Mrs. Houston Clinton, Mrs. M. E. McLean, and Mrs. Russell Rarey. A Sunday Tea, luncheon at the famed Kungsholm Restaurant and a sightseeing tour were among the activities enjoyed by the ladies.

NCSA Ladies Luncheon, Kungsholm Restaurant

Regional Vice Presidents for 1956
of the
National Crushed Stone Association

O. E. BENSON
Eastern
Delaware,
Maryland,
New Jersey,
New York,
Pennsylvania,
District of Columbia

A. J. CAYIA
Northern
Michigan,
Minnesota,
Montana, Nebraska,
North Dakota,
South Dakota,
Wisconsin

H. A. CLARK
Midwestern
Illinois, Indiana,
Iowa, Kansas,
Missouri

H. CLINTON
Southwestern
Arizona, Arkansas,
Louisiana,
New Mexico,
Oklahoma, Texas

R. G. L. HARSTONE
British Commonwealth
Dominion of Canada,
United Kingdom,
Australia,
New Zealand,
Union of
South Africa

A. W. McTHENIA
Central
Kentucky, Ohio,
Tennessee,
West Virginia

W. C. ROWE
New England
Connecticut, Maine,
Massachusetts,
New Hampshire,
Rhode Island,
Vermont

N. SEVERINGHAUS
Southeastern
Alabama, Florida,
Georgia,
Mississippi,
North Carolina,
South Carolina,
Virginia

B. G. WOOLPERT
Western
California,
Colorado, Idaho
Nevada, Oregon,
Utah, Washington,
Wyoming,
Territory of Hawaii

WAYNE W. KING
W. S. Tyler Co.
Baltimore, Md.
Chairman
Manufacturers Division

L. A. EIBEN
Northern Blower Co.
Cleveland, Ohio

EXECUTIVE COMMITTEE

of the

MANUFACTURERS DIVISION

National Crushed Stone Association

for the year 1956

N. E. KELB
Cumberland Quarries, Inc.
Indianapolis, Ind.
President
National Crushed
Stone Association

R. D. KETNER
General Electric Co.
Schenectady, N. Y.

B. R. MALONEY
E. I. du Pont
de Nemours & Co.
New York, N. Y.

H. W. NEWTON
Barber-Greene Co.
Aurora, Ill.

W. A. RUNDQUIST
Pioneer Engineering
Works, Inc.
Minneapolis, Minn.

A. T. Goldbeck Honored At Annual Banquet

A feature of the Annual Banquet was the presentation of a gift to A. T. Goldbeck, Engineering Director of NCSA, in appreciation of his 31 years of service to the Association. Making the presentation was Past President A. L. Worthen, whose remarks are found on page 14 of this issue of the Journal.

Mr. Worthen praised retiring President T. C. Cooke for his initiative, effort, and leadership during his two-year term of office. After an expression of gratitude for the cooperation extended by everyone, Mr. Cooke introduced the newly-elected President of NCSA, Norman E. Kelb of Indianapolis, Indiana, who expressed his appreciation at having been so honored.

Along with the recognition tendered the other distinguished guests of the head table, President Cooke gave special mention to W. R. Sanborn, President of the Lehigh Stone Company, Kankakee, Illinois, who, on June 4, 1956, will complete 50 years of active management in the stone industry. Mr. Sanborn was also cited as being among those present at the first organizing meeting of NCSA.

Social Hours Enjoyed

The social side of the Convention was widely acclaimed, too, with large turnouts for the two luncheons, the NCSA Cabaret, and the Annual Banquet. The excellent presentations of the guest speakers, Messrs. Bowie, Gilmore, and Collins, were well received, and an occasion of just plain fun and relaxation—the Monday evening Cabaret with its highly enjoyable floorshow followed by dancing, will be remembered long and pleasantly by everyone in attendance.

Manufacturers Exposition Attractive To Many Visitors

L. W. Shugg
Director of Exhibits

An outstanding feature of the Convention was the Biennial Exposition of the Manufacturers Division. Everyone in attendance was emphatic in his praise of the many attractive displays, and each of the exhibitors is to be congratulated for his smartly designed layout. Much credit is also due L. W. Shugg for the experienced and capable manner in which he functioned as Director of Exhibits.

Without doubt, this was the finest of many fine Expositions. This was borne out by the extreme interest of the large number of visitors to the Exposition Hall.

Wayne W. King Heads Manufacturers Division

At the Manufacturers Division Luncheon and Annual Meeting on Tuesday, February 21, 1956, with some 200 members and guests present, Wayne W. King of Baltimore, Maryland, was unanimously elected to succeed B. R. Maloney as Chairman of the Division.

The report of the Nominating Committee, previously circulated by mail to all member companies, was presented by Committee Chairman Irwin F. Deister and resulted in the unanimous election of the following to the offices as designated below:

CHAIRMAN

Wayne W. King, W. S. Tyler Co., Baltimore, Md.

VICE CHAIRMEN

L. A. Eiben, Northern Blower Co., Cleveland, Ohio

H. W. Newton, Barber-Greene Co., Aurora, Ill.

W. A. Rundquist, Pioneer Engineering Works, Minneapolis, Minn.

REPRESENTATIVES ON NCSA BOARD

B. R. Maloney, E. I. du Pont de Nemours & Co., New York, N. Y.

R. D. Ketner, General Electric Co., Schenectady, N. Y.

DIRECTORS

H. M. Albers, Kensington Steel Co., Chicago, Ill.

F. E. Briber, Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

W. E. Collins, Jr., Atlas Powder Co., Wilmington, Del.

A. G. Crockett, Mack Motor Truck Corp., New York, N. Y.

R. M. Dickey, Bucyrus-Erie Co., So. Milwaukee, Wis.

E. T. Eggers, American Steel & Wire Division, United States Steel Corp., Cleveland, Ohio

George D. Fraunfelder, Easton Car & Construction Co., Easton, Pa.

E. S. Gill, Gill Rock Drill Co., Lebanon, Pa.

J. W. Hardesty, Baldwin-Lima-Hamilton Corp., Construction Equipment Division, Lima, Ohio

H. R. Harrington, Goodyear Tire & Rubber Co., Inc., Akron, Ohio

G. C. Holton, American Cyanamid Co., New York, N. Y.

J. M. Hume, Pettibone Mulliken Corp., Chicago, Ill.

G. H. Keppel, Birdsboro-Buchanan Crusher Dept., Birdsboro Steel Foundry & Mach. Co., Birdsboro, Pa.

K. F. Lange, Link-Belt Co., Chicago, Ill.

L. L. Morgan, Caterpillar Tractor Co., Peoria, Ill.

F. A. Pampel, Chain Belt Co., Milwaukee, Wis.

NEWLY ELECTED TO MANUFACTURERS DIVISION BOARD

F. E. Briber, Jr.
Allis-Chalmers Mfg. Co.
Milwaukee, Wis.

A. G. Crockett
Mack Motor Truck Corp.
New York, N. Y.

L. L. Morgan
Caterpillar Tractor Co.
Peoria, Ill.

H. H. Schaper
Smith Engineering Works
Milwaukee, Wis.

R. S. Wells
Stephens-Adamson Mfg. Co.
Aurora, Ill.

L. A. Rhodes, Jeffrey Mfg. Co., Columbus, Ohio
H. H. Schaper, Smith Engrg. Works, Milwaukee, Wis.
C. D. Smith, Joy Manufacturing Co., Dallas, Texas
H. R. Stickel, White Motor Co., Cleveland, Ohio
Gilfry Ward, American Manganese Steel Division, American Brake Shoe Co., Chicago, Ill.
C. S. Weber, Thew Shovel Co., Lorain, Ohio
R. S. Wells, Stephens-Adamson Mfg. Co., Aurora, Ill.

As provided in the Division By-Laws, the Chairman, Vice Chairmen, Division Representatives on the NCSA Board, and the NCSA President are ex officio members of the Manufacturers Division Board of Directors. The Chairman of the Manufacturers Division also serves on the NCSA Board in an ex officio capacity.

In accepting the Chairmanship of the Division for 1956, Mr. King humbly expressed his thanks for the honor accorded him by the membership and pledged his efforts to continue the outstanding achievements of those Chairmen before him.

Speaking in behalf of the Division membership, Past Chairman Deister praised Mr. Maloney for his leadership during the past two years, and presented him with the gavel used by Mr. Maloney as Chairman. The gavel was inscribed as follows:

Presented To
B. R. Maloney
Chairman 1954-1955
Manufacturers Division
National Crushed Stone Association
In grateful appreciation of services rendered

In an appreciative response, Mr. Maloney thanked the officers and Boards of Directors of the Manufacturers Division and of NCSA for their cooperation during his tenure of office. He also expressed appreciation to the Division membership for its wholehearted assistance, and for the opportunity of serving as Chairman.

Manufacturers Division, Annual Business Meeting Luncheon, Conrad Hilton Hotel, Chicago, Ill., February 21, 1956

Division Membership Reaches New High

An accomplishment of particular interest was announced at the Annual Business Meeting by L. A. Eiben, Membership Committee Chairman. After introducing eight new members, Mr. Eiben stated that the strength of the Manufacturers Division had reached an all-time high of 111 members.

Another record of Division growth was noted in connection with the Biennial Exposition where approximately 17,000 square feet of display space was used by 71 exhibitors. This exceeds the previous high use of Exposition space, set in 1954.

Members of New Board Manufacturers Division

Top Row, left to right:

J. W. Hardesty, Baldwin-Lima-Hamilton Corp., Lima, Ohio

C. S. Weber, Thew Shovel Co., Lorain, Ohio

C. Darrell Smith, Joy Manufacturing Co., Dallas, Texas

H. M. Albers, Kensington Steel Co., Chicago, Ill.

J. M. Hume, Pettibone Mulliken Corp., Chicago, Ill.

G. H. Keppel, Birdsboro-Buchanan Crusher Dept., Birdsboro Steel Foundry and Machine Co., Birdsboro, Pa.

Middle Row, left to right:

W. E. Collins, Jr., Atlas Powder Co., Wilmington, Del.

F. E. Briber, Jr., Allis-Chalmers Mfg. Co., Milwaukee, Wis.

R. S. Wells, Stephens-Adamson Mfg. Co., Aurora, Ill.

F. A. Pampel, Chain Belt Co., Milwaukee, Wis.

H. R. Harrington, Goodyear Tire & Rubber Co., Inc., Akron, Ohio

G. D. Fraunfelder, Easton Car & Construction Co., Easton, Pa.

E. T. Eggers, American Steel & Wire Div., United States Steel Corp., Cleveland, Ohio

Bottom Row, left to right:

G. C. Holton, American Cyanamid Co., New York, N. Y.

J. R. Boyd, Secy., Manufacturers Division, NCSA, Washington, D. C.

H. W. Newton, Barber-Greene Co., Aurora, Ill.

L. A. Eiben, Northern Blower Co., Cleveland, Ohio

Wayne W. King, W. S. Tyler Co., Baltimore, Md., *Chairman*

Mrs. E. S. Gill, Gill Rock Drill Co., Lebanon, Pa.

B. R. Maloney, E. I. du Pont de Nemours & Co., New York, N. Y.

W. A. Rundquist, Pioneer Engrg. Works, Inc., Minneapolis, Minn.

W. M. Smith, General Mine Foreman
Bell Mine of Warner Company, Bellefonte, Pa.
Winning Plant of 1954 NCSA Safety Contest

Safety Awards Presented on Monday

At Monday's Greeting Luncheon, well-deserved recognition and awards were given representatives of the 21 winning plants in the NCSA Safety Contest. The presentations were made by H. H. Kirwin, Chairman of the NCSA Accident Prevention Committee. For the outstanding accomplishment of 246,689 man-hours worked without a lost-time accident during the contest year, the Warner Company's Bell Mine, Bellefonte Division, Bellefonte, Pennsylvania, was awarded the handsome bronze plaque, donated by the *Explosives Engineer* magazine. Reproductions of the plaque in the form of Certificates of Honorable Mention were presented to representatives of each perfect-record plant participating in the safety contest.

As further recognition of the importance of safety programs and of the part played by individuals, the employees of each winning plant are presented with a certificate by the National Crushed Stone Association.

WINNERS 1954 NSCA *Safety Contest*

MAN-HOURS WITHOUT A LOST-TIME ACCIDENT

WINNER

264,689 — **BELL MINE** *Bellefonte, Centre County, Pa.*
WARNER COMPANY, BELLEFONTE DIVISION
HERSCHELL A. CORRE, SUPT.

HONORABLE MENTION

○	223,902	GREYSTONE QUARRY HENDERSON, VANCE COUNTY, N.C.	GREYSTONE GRANITE QUARRIES E. L. BRANTLEY, SUPT.
○	119,379	NORTH BRANFORD No. 7 QUARRY NORTH BRANFORD, NEW HAVEN COUNTY, CONN.	NEW HAVEN TRAP ROCK CO. ROBERT D. BREWER, SUPT.
○	104,065	KIMBALLTON MINE KIMBALLTON, GILES COUNTY, VA.	STANDARD LIME & CEMENT CO. G.C. LARKIN, SUPT.
○	101,135	RED HILL QUARRY CHARLOTTESVILLE, ALBEMARLE COUNTY, VA.	SUPERIOR STONE CO. R. C. WILLIAMS, SUPT.
○	95,538	ROCK HILL QUARRY QUAKERTOWN, BUCKS COUNTY, PENNA.	GENERAL CRUSHED STONE CO. E. Z. COLE, SUPT.
○	91,161	WOODLEAF QUARRY WOODLEAF, ROWAN COUNTY, N.C.	SUPERIOR STONE CO. H.C. BURGESS, SUPT.
○	84,730	JORDANVILLE QUARRY JORDANVILLE, HERKIMER COUNTY, N.Y.	GENERAL CRUSHED STONE CO. OLIVER C. DIETSCHLER, SUPT.
○	69,750	WATERTOWN QUARRY WATERTOWN, JEFFERSON COUNTY, N.Y.	GENERAL CRUSHED STONE CO. JOHN P. COX, SUPT.
○	58,707	UNION FURNACE QUARRY TYRONE, BLAIR COUNTY, PENNA.	WARNER CO.–BELLEFONTE DIV. JESS T. STRINGER, SUPT.
○	56,848	CEDAR HOLLOW QUARRY DEVAULT, CHESTER COUNTY, PENNA.	WARNER COMPANY GEORGE PURNELL, JR., SUPT.
○	54,476	YELLOW ROCK MINE YELLOW ROCK, LEE COUNTY, KY.	KENTUCKY STONE CO. D. L. LOVENS, SUPT.
○	46,784	CAPE GIRARDEAU QUARRY CAPE GIRARDEAU, CAPE GIRARDEAU COUNTY, MO.	FEDERAL MATERIALS CO. A. W. ZIMMER, JR., MGR.
○	46,213	PROSPECT STONE PLANT No. 6 PROSPECT, ONEIDA COUNTY, N.Y.	EASTERN ROCK PRODUCTS, INC. JESSE HANEY, SUPT.
○	30,382	TYRONE MINE LAWRENCEBURG, ANDERSON COUNTY, KY.	KENTUCKY STONE CO. WESLEY BLAIR, SUPT.
○	27,104	AVOCA QUARRY AVOCA, JEFFERSON COUNTY, KY.	JEFFERSON COUNTY STONE CO. EMIL BERRY, PRESIDENT
○	20,134	PLANT No. 4 QUARRY KNIPPA, UVALDE COUNTY, TEXAS	SOUTHWEST STONE CO. T. O. JONES, SUPT.
○	19,395	RANDVILLE QUARRY SAGOLA, DICKINSON COUNTY, MICH.	SUPERIOR ROCK PRODUCTS CO. SHERMAN L. HAMBY, SUPT.
○	18,336	No. 7 QUARRY ELSBERRY, LINCOLN COUNTY, MO.	COLUMBIA QUARRY CO. EARL K. PFLASTERER, SUPT.
○	14,902	HIGH BRIDGE MINE HIGH BRIDGE, JESSAMINE COUNTY, KY.	KENTUCKY STONE CO. R. I. McDONALD, SUPT.
○	10,673	ELKTON QUARRY ELKTON, TODD COUNTY, KY.	KENTUCKY STONE CO. JOHN PERL WILLIAMS, SUPT.

Presentation of
NCSA SAFETY AWARDS
Monday Luncheon · Grand Ballroom

Emphasis on safety is growing steadily. Several companies were represented by more than one contest-winning plant with the Kentucky Stone Company placing four plants in the list of 21 winners. The General Crushed Stone Company and the Warner Company were honored three times each while the Superior Stone Company had two award-winning quarries.

NCSA Safety Contest Winners

Top Row, left to right:

W. M. SMITH, General Mine Foreman, Bell Mine of Warner Co., Bellefonte Division, Bellefonte, Pa.

GEORGE I. PURNELL, JR., Supt., Cedar Hollow Quarry, Warner Co., Devault, Pa.

JESSE HANEY, Supt., Prospect Stone Plant No. 6, Eastern Rock Products, Inc., Prospect, N. Y.

EARL K. PFLASTERER, Supt., No. 7 Quarry, Columbia Quarry Co., Elsberry, Mo.

E. Z. COLE, Supt., Rock Hill Quarry, General Crushed Stone Co., Quakertown, Pa.

OLIVER C. DIETSCHLER, Supt., Jordanville Quarry, General Crushed Stone Co., Jordanville, N. Y.

JOHN P. COX, Supt., Watertown Quarry, General Crushed Stone Co., Watertown, N. Y.

ROBERT D. BREWER, Supt., North Branford No. 7 Quarry of New Haven Trap Rock Co., North Branford, Conn.

Bottom Row, left to right:

VERNE C. MORGAN, Vice President and Treasurer, Kentucky Stone Co., Louisville, Ky.

E. L. BRANTLEY, Supt., Greystone Granite Quarries, Inc., Henderson, N. C.

H. C. BURGESS, Supt., Woodleaf Quarry, Superior Stone Co.,

R. C. WILLIAMS, Supt., Red Hill Quarry, Superior Stone Co., Charlottesville, Va.

EMIL BERRY, President, Avoca Quarry, Jefferson County Stone Co., Avoca, Ky.

G. C. LARKIN, Supt., Kimballton Mine, Standard Lime and Cement Co., Kimballton, Va.

A. W. ZIMMER, JR., Mgr., Cape Girardeau Quarry, Federal Materials Co., Cape Girardeau, Mo.

W. F. WISE, President, Southwest Stone Co., Dallas, Texas

40th Annual Convention

NATIONAL CRUSHED STONE ASSOCIATION

Miami Beach, Florida

WEEK OF JANUARY 13, 1957

An Appreciation To Albert T. Goldbeck

Engineering Director, National Crushed Stone Association

ALBERT T. GOLDBECK

AN appreciation to Albert T. Goldbeck, Engineering Director of the National Crushed Stone Association, for 31 years of devoted service was given by Past President A. L. Worthen on Wednesday evening, February 22, 1956, before one of the largest gatherings ever to attend an Annual Banquet. Mr. Worthen, on behalf of the entire membership spoke as follows:

"I am greatly pleased that President Cooke has asked me to speak to you upon this occasion.

"I am sure you all agree with me that it is most unfortunate that Otho Graves is not with us to tell you much about the man whom he was instrumental in bringing to the Association. As you know, Mr. Goldbeck, under the NCSA retirement plan, will relinquish his duties as Engineering Director next August. He has, however, at the request of the Board of Directors, agreed to continue with the Association on a consulting basis, for which we are all greatly relieved.

"In 1925 Otho M. Graves, then President of the Association, mainly through his own efforts and initiative, consummated a plan to transfer the NCSA headquarters from Columbus, Ohio, to Washington, D. C., and secured A. T. Goldbeck, then chief of the Division of Tests and Research, U. S. Bureau of Public Roads, to join the Association as Director of a newly established Bureau of Engineering.

"In the October 12, 1925, issue of the National Crushed Stone Association Bulletin, Mr. Graves explained to the members the plan and, under the heading 'Reasons prompting the Association to enter into a new form of activity,' indicated fourteen functions of the new Bureau. I shall not recite all fourteen, but feel you will be interested in three. I quote:

'To review facts which have been established in respect to crushed stone through field and laboratory tests, in order that such facts may be made available and plainly set forth for the benefit of both producer and consumer.

'To interpret the results of researches on aggregates in an unbiased, straightforward manner to the end that there will be no misunderstanding of the limitations and meaning of research results in the minds of the users or producers.

'In general, to advance the interests of crushed stone in a frank, straightforward, scientific and ethical manner, free from bias and without recourse to unworthy attacks on any other aggregates.'

"You all know how conscientiously Mr. Goldbeck has for over 30 years carried out these precepts.

"Albert, there is nothing I can say of you which could add to your reputation as an engineer, and particularly as a foremost authority on highway and related construction. You have received countless honors from many engineering societies. I feel, however, that I speak for all members of the Association when I tell you that your efforts in our behalf are largely responsible for the progress and success of this Association since 1925.

"Although you do not retire until next August, the members of the Association felt that this Annual Meeting is the appropriate time to express our appreciation for your many years of service to our Association and the aggregate industry.

"In considering an appropriate gift, we thought it only fitting to select something which could also be enjoyed by Mrs. Goldbeck who, like all wives, must have had a part in your work. On behalf of all of the members of NCSA, it is my pleasure to hand you a replica of a Chrysler New Yorker automobile. It will be your privilege to select a car to suit your tastes. With this gift goes our blessing and the hope

(*Continued on Page 19*)

The Past Thirty Years[1]

By A. T. GOLDBECK
Engineering Director
National Crushed Stone Association
Washington, D. C.

TO me this is an important occasion, for this is the last Convention I shall have the privilege of addressing in my present capacity as Engineering Director. Thirty years have passed since I became connected with the National Crushed Stone Association, and it seems fitting that I review with you just a few of the more important engineering activities in which we have been engaged in an effort to help the crushed stone industry.

At the very beginning I decided that my value to the Association would continue only as long as I maintained my engineering status, dealing with facts in an engineering way. It is my belief that our somewhat rigid policy, from which I hope we have not departed seriously, was certainly best for you and, further, it has resulted in establishing the reliability of the technical work of the National Crushed Stone Association.

Sometimes it is difficult to point to tangible accomplishment as the result of Association work, but today I invite you to go back with me over the past thirty years so that we might scan the record. Some of you may find it interesting to have at least a few of our technical problems again brought to light and to learn, perhaps for the first time, what your Association has done to combat them. Such a review will indicate some of the procedures we have used in attempting to act effectively in your behalf, and it may open your eyes to the kind of service you can get from the Association merely by asking for it.

The solution of some of these problems has been a prolonged affair but while we were gaining ground on one particular problem, we might also have been working on many other problems presented to us for solution. I do not intend to bore you with details, for if I told the whole story, days would be required instead of minutes.

Concrete Studies

Thirty years ago when our work was started, the proportioning of concrete by arbitrary proportions, such as 1:2:4 was still in vogue. One part of cement, two parts of sand, and four parts of coarse aggregate were specified, no matter whether rounded gravel or angular crushed stone was used, no matter what the gradation and maximum size was to be, and no matter whether the sand was wet or dry. There is little wonder that contractors had difficulty getting workable concrete with crushed stone. Nobody seemed to realize that moist sand sometimes had 30 per cent more volume than dry sand, and consequently if the sand was moist it was swollen and a cubic foot of it contained much less solid sand than if the sand had been dry. So the proportions, 1:2:4, frequently resulted in concrete which had far too little sand in it to separate the pieces of stone coarse aggregate and consequently the concrete was harsh working. We were aware of this difficulty and to assist in overcoming it technical Bulletin No. 1 was written entitled "The Bulking of Sand and Its Effect on Concrete." That Bulletin was well received and it undoubtedly helped a number of our members who were supplying stone for concrete.

Another difficulty stone had to contend with was the growing use of the water-cement ratio specification, advocated by the Portland Cement Association. It was based on tests, as a result of which a principle was announced to the effect that, all other things being equal, there was a relationship between the water-cement ratio and the compressive strength of concrete. But this relationship is disturbed by differences in cement, differences in surface characteristics of the aggregates, and by a number of other influences which were not taken into account.

[1] Presented at the 39th Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 20-22, 1956

The water-cement ratio specification has penalized stone over the years because it resulted in the requirement of more cement in stone concrete than in gravel concrete. Our Bulletin No. 3 pointed out the inconsistencies of this type of specification. Later we made a number of tests on concrete aimed at its proper proportioning for highways. These tests are described in our Bulletin No. 7. They showed that the beam strength of concrete undoubtedly was influenced by the type of coarse aggregate and its surface characteristics. It was shown that, when the cement factor was alike, stone concrete frequently tested higher in beam strength than the competing gravel concrete, but, on the other hand, this was not always so and in fact the reverse might at times be true.

A method was described in Bulletin No. 7 for the design of concrete having any desired modulus of rupture. There can be little doubt that the procedures advocated in Bulletin No. 7 helped materially to establish the beam test as a most suitable test for highway concrete, but we were still not satisfied with the progress being made toward a more equitable method for proportioning concrete which would not penalize crushed stone.

Cooperative tests were made between the Bureau of Public Roads and the New Jersey State Highway Department involving trap rock and gravel, and in the municipal laboratory in the Borough of the Bronx, New York, involving dolomite vs gravel. Still another cooperative test on concrete involving different aggregates was conducted by the Connecticut State Highway Department. These cooperative tests came about in part as a result of our requests. Incidentally, the fairness of both the Sand and Gravel Association and the Crushed Stone Association technicians was paid a compliment by the fact that we both participated very actively in these cooperative tests by invitation. Our policy of conducting our tests in an engineering, unbiased manner was paying dividends.

The Borough of the Bronx tests showed very conclusively that we could use the same cement factor with both types of aggregates and design concrete which would have essentially the same compressive strength. And so, as a result of continuing work in our Laboratory, we devised a method for proportioning concrete which is described in our Bulletin No. 11 entitled "A Method for Proportioning Concrete for Strength, Workability, and Durability." This method takes account of almost all of the variations to be found in aggregates—variations including specific gravity, shape of particle, gradation of both the fine and the coarse aggregate, and this is accomplished in an extremely simple way.

Bulletin No. 11 in its final revised form as of 1953 has been sent out by the thousands and is employed as a textbook in a great many engineering colleges in this country. Likewise it has been sent abroad and has had very wide usage. Neither stone nor gravel is penalized because both are required to have the same cement factor. This method really works and has been used with success on very large structures, including the Idlewild Airport on Long Island.

This whole episode of the final development of the proper specification and method for proportioning concrete to overcome a handicap from which stone undoubtedly suffered in the old days, reminds me of the mountain climber who was asked "Why do you come back repeatedly, year after year, in an effort to conquer this particular mountain?" His reply was "Because it is there." The very fact of its existence was a challenge which he could not resist, and similarly we in the Association kept our challenge before us continuously and came back to our concrete problem time and again. But, all this was going on over a period of 17 years or more and, in the meantime, we were faced with many other problems.

Flexible Pavement Design

Shortly before the second World War we saw the desirability of getting some information on the design of airport runways for carrying heavy wheel loads. There could be little question that many airports would be built with bituminous concrete laid on a proper foundation, but the question was "How thick should those runways be to support the heavy wheel loads of large planes?" We did not know of any adequate theory that would tell us how to design such surfaces but, fortunately, in about 1915, while connected with the U. S. Bureau of Public Roads, I was called upon to determine how wheel loads placed on the surface of a fill were distributed through that fill. A special soil pressure measuring cell was devised and by a slight adaptation we found

it very useful in our tests for flexible pavement design.

We built a bin in which a subgrade was placed and upon which pavement surfaces of different thicknesses were built. Loads were applied to those surfaces and the pressures were measured on the underlying subgrade. We obtained thousands of readings but, just as in other investigations, unless you can generalize these individual readings and develop them into some kind of a pattern, that is, devise a theory which has general application, the readings as yet are only potentially useful. Fortunately, we were able to discover that the readings did conform to a pattern and consequently we were able to devise formulas for determining the required thickness of a flexible pavement. This work has been described before the Highway Research Board and also in several of our Crushed Stone Journal articles.

Recently we have had occasion to check the thicknesses as determined by the formulas derived from our tests against the recent WASHO Test Road results obtained in Idaho from the flexible road test which has just been terminated. The comparison of our theory with the actual test results was most gratifying. As a result of our tests and observations, we feel that it is possible to advocate certain fundamental principles which should be observed in the design of the flexible pavement.

1. The over-all thickness between the subgrade and the top of the pavement should be such that the pressures which reach the subgrade should never exceed the bearing capacity of the subgrade in its softest condition.

2. In view of the fact that the intensity of pressure diminishes from a maximum at the top to a minimum at the level of the subgrade, it is feasible and economical to use layers of varying strength, that at the bottom being the weakest and the top layer, the surface layer, being the strongest.

3. It is quite necessary to design each layer so that the pressures which reach the layer beneath will not be excessive. Sometimes this principle is overlooked. The top courses must resist lateral as well as vertical forces from wheel loads and must have sufficient thickness and strength to resist these forces combined.

4. It is desirable to use "stepped" construction along the sides of the road in order to spread the subgrade pressures laterally to the best advantage and thereby tend to make the pavement at the side of the road as strong as that at the center. Furthermore, it is desirable that the road shoulders be water-proofed so that the subgrade at the sides under the shoulders will not be softened.

We have been able to use the method of flexible pavement design resulting from the National Crushed Stone Association investigations to excellent advantage for the benefit of our members. There is no question that this flexible pavement investigation, although of a fundamental nature, has paid off manyfold and will do so in the future.

I cite the two foregoing types of investigation, that on concrete and that on flexible pavement design, as being of a fundamental nature. They are large, over-all investigations which are aimed at the good of the entire membership. We saw the necessity for them and we went after them with considerable energy, with very rewarding results.

Studies in Bituminous Surfaces

Very early in our work we began to study bituminous concrete in many of its aspects, including

a. Its proper proportioning
b. The question of stripping of asphalt from the aggregate due to water action
c. Special studies of stability and of durability
d. Studies of the effect of different kinds of dust filler

These studies would constitute a book of reports if they were fully described.

Early in our work we felt very much handicapped because there seemed to be no laboratory test which we could depend upon to simulate service behavior. There were in existence certain laboratory tests for stability, but we wished to be able to compare such tests with actual service behavior or with simulated service behavior. And so, around 1933, we designed and built a special test track in our Laboratory which has been described in our Crushed Stone Journal and elsewhere. This track has been of real value in making comparative studies of the stability and durability of bituminous mixtures, and every once in a while we find that it is of very great assistance in making other kinds of studies as well. Time permits a mere mention of this extremely useful laboratory tool. With it we have

studied bituminous surface treatments, the beneficial influence of a screenings sub-base in preventing the upward intrusion of the subgrade into macadam, the stability and durability of various types of bituminous paving mixtures, the effect of dust filler on bituminous concretes, and of methods for overcoming the detrimental effects of certain fillers. In one case, in just a few days time, we were able to solve a problem in bituminous concrete for one of our producers who was very much in need of immediate results.

Aggregate Studies

We have made a number of studies on aggregates, including stone dust and its effect on concrete, the effect of flat and elongated pieces, studies of the sodium and the magnesium sulfate tests, laboratory studies in the prevention of the segregation of aggregates, and one rather large series of investigations having to do with the bearing value of railroad ballast. The very great stability of stone ballast was amply demonstrated.

We have done a lot of work on stone sand for concrete structures and for use in pavements, and that required also the devising of a special test for determining particle shape. This test when made in the proper manner, has worked out very well.

Several of our recent series of tests have had to do with a problem which is becoming of extreme importance to the crushed stone industry. I refer to the problem of pavement slipperiness. Speeds of vehicles have been increasing with increasing horsepower and it has been found that certain aggregates do wear smooth and lose their gritty surface. Several very large series of comparative tests have been made in which we have used our circular track as a means for the preparation of the test sections to bring them to the degree of smoothness they actually obtain in service; and after having produced that kind of surface, we proceeded to measure its slipperiness by means of a specially devised and rather simple piece of apparatus, a picture of which you will find in the December 1955 issue of the Crushed Stone Journal.

In addition to these investigations, we have performed innumerable investigations for a great many of our member companies upon their request. Perhaps it will be of some interest, especially to our newer members, to know that we do special research work as a part of our service.

Classification of Kinds of Laboratory Research Performed by NCSA

In looking back over the years, it would seem that the kinds of research performed in our Laboratory may be given a rough classification as follows:

I. Work of a basic nature which we originate because we see that it is needed to help the industry. For example:

1. Work leading to the final development of our concrete proportioning method, described in Bulletin No. 11
2. Work which finally led to our method for designing the flexible pavement
3. Work on slipperiness of pavements and how to overcome it

II. Research to overcome some particular difficulty had by a member company. For example, durability tests, using a unique method for determining the acceptability of a certain quarry for an important concrete pavement.

III. Research of a development nature, typified by the following examples:

1. To determine the quality of newly drilled cores so as to advise the owner regarding suitability of the rock for commercial usage
2. Tests to determine the most appropriate proportions of concrete with particular materials

IV. Check testing

Sometimes producers have trouble with borderline stone because of failure of that stone to pass specifications. Testing machines or testing methods may be at fault and in that case, check tests are used to study the trouble. Cooperative tests are arranged with the laboratory in question and frequently the source of trouble is revealed.

Testing Work Involves Special Investigations

There have been a great many variations of the above examples, but those cited are at least typical illustrations. It will be noted that the testing work we do is not routine—it all involves special investigations. We do not perform routine testing of samples submitted day after day to determine the continuing compliance of materials with specifications. That is the type of work which can best be done by commercial testing laboratories.

You will gain some idea of the extent to which we have engaged in research for our members when I tell you that in the past seven years alone we have conducted 252 research projects—one of them requiring 12,000 separate determinations, and others almost as extensive. Likewise some 300 articles and bulletins have been published and numerous laboratory reports prepared.

While all this has been going on, our Field Engineer has been doing very extensive and useful work in the field. Also we have conducted six Short Courses for our members, requiring careful preparation and the willing services of fifty or more speakers of national prominence in their respective fields.

Well, even though I have barely scratched the surface, it looks as if we have been kept fairly busy, and that is really the fact. I am afraid this accounting of the past thirty years may have sounded to you like the oration of the old Indian chief who, at the end of a raiding campaign, harangued his tribe and bragged about the number of scalps he had taken. I hope I did not sound that way, but I do wish to emphasize with you, that in the National Crushed Stone Association you have an organization which has been alert and which has been extremely active in your behalf.

In conclusion, I wish to pay very high tribute to our entire staff. In them you have a hard working, loyal set of employees who have done outstanding work. They deserve all the support you can give them in their future endeavors. Personally, I have enjoyed working with you and for you; you have been kindly and understanding. Although I am retiring from my present position within several months, I hope to be of some help to the Association in the future.

An Appreciation To Albert T. Goldbeck

(*Continued from Page 14*)

that you and Mrs. Goldbeck will enjoy the car and many years of happiness together."

Mr. Goldbeck responded as follows:

"I surely am glad my wife is here tonight. For almost forty years I have been trying to convince friend wife that her husband is a most remarkable fellow. Now she can be certain and, Mr. Ex-President, you surely have done me a great service.

"As a matter of fact, I feel somewhat like the colored woman who was attending the funeral services for her no-account husband. The preacher became more eloquent by the minute and finally, after an unusual flight of oratory, she whispered to her son 'Rastus, supposin' you go take another little peek in there and see if dat really am yo' pappy.'

"I'll never forget the day Otho M. Graves stopped in the United States Bureau of Public Roads and invited me to become the Research Engineer for the National Crushed Stone Association. He told me he had become President and the Association was about to be reorganized with offices in Washington.

"At that time I was Chief of the Division of Tests and Research of the Bureau of Public Roads. This was a division having some 60 research engineers, chemists, and their assistants, and with an annual appropriation of about a quarter of a million dollars. I told Otho that after working with that kind of an organization, I didn't quite see how I, alone, could be of much help to the Association. But, as most of you know, he was very persuasive and after some study, I later told him I thought I saw ways of being useful and I agreed to give the Association work a trial.

"That was a very hard decision to make, but let me tell you that now I do not regret it. You have been wonderfully fine folks to work for; the work has been exceedingly interesting; it has been a lot of fun.

"Mr. Ex-President, thank you very much for your very gracious remarks and I am simply overwhelmed by this very substantial token of your collective expressions of appreciation of the work I have tried to perform for the Association.

"Mr. President, Ladies and Gentlemen, I am sure that Mrs. Goldbeck joins me in expressing our very great thanks."

Plant Control of Bituminous Concrete Mixes[1]

By DONALD D. DAGLER
District Engineer
Asphalt Institute
Harrisburg, Pa.

Bituminous Concrete Plant Control

IN building an asphaltic concrete highway or flexible type pavement, I feel that it takes four major controls to arrive at a good end result.

First, good design. We feel that today methods of design are such that we are getting good pavements.

Second, good plant control.

Third, an adequate foundation on which to place your asphaltic concrete, without which no road, regardless of what it is built of, will work.

Fourth, the placing of the material under controlled methods.

Today, we have time to speak about only one of these four. We are going to discuss plant control. Some of it may be a little superfluous to some of you who have seen and operated plants. However, we found in Pennsylvania years ago that it was necessary to educate people in the use of asphaltic concrete. I think a good deal of the reason for highway departments in small cities, boroughs, and so on, not using more asphalt is because they do not understand it.

In my travels throughout the entire eastern part of this country in the last year and a half since being with the Asphalt Institute, I have found that the plant producers are endeavoring to produce a good asphaltic concrete. A good many of our troubles today, we feel, are in the placing of it. We have endeavored to educate people in the placing of bituminous concrete. However, in our plant control we feel there are some things that can be improved upon, and I will try to point out some of these to you.

Figure 1 shows an operation in Pennsylvania. In this picture you will notice that there are two plants. The reason for two plants is that this producer makes a hot and cold mix to satisfy his customers.

You cannot make hot and cold material in the same plant with only one pug-mill. The hot material depends on heat for workability. The cold material is usually a cutback of some kind, either applied at the mixer or purchased in the asphalt.

There are two reasons for not mixing hot and cold mixes in the same pug-mill. First, it is a dangerous operation. If you have an operation with a cutback in it which probably is high in naphtha content, it is apt to flash if you have just mixed a hot batch in the pug-mill. Secondly, if you were to put a hot batch into the pug-mill directly behind a cold batch, you will lose some of the heat in the material, which also means a loss of workability on the job.

The back plant in this particular case is used for cold mixes, whereas the front plant is used for hot mixes. We are going to discuss hot mixes, for the reason that today about 80 per cent of the mixes produced are hot asphaltic concrete, as we have found over a period of years that hot mixes are more durable and result in longer-lasting pavements.

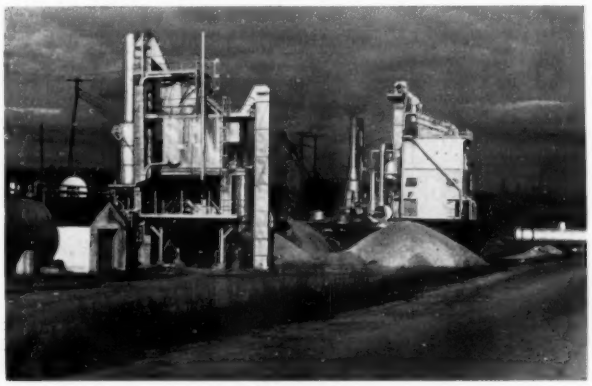


FIGURE 1

Asphalt Tanks

Now we come to the asphalt tanks, which of course are important. Today, because of the many business connections that you have with these vari-

[1] Presented at the 39th Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 20-22, 1956

ous asphalt plants, it is necessary for you to have two or three asphalt tanks. You may get jobs where it is necessary to use 85 to 100 penetration asphalt, and you will have other jobs where 60 to 70 penetration is necessary, or even sheet asphalts down to 55 to 70 penetration asphalt.

Since trucks have been utilized to transport asphalt from the refinery to the asphalt plant, it is very necessary that these trucks be clean of fuel oil, naphtha, kerosene, or such lubricating materials that will cutback the asphalt. Although the refineries try very hard to inspect the trucks before loading, they sometimes miss one. If an 85 to 100 penetration asphalt is cutback, this means an increase in penetration which will result in a slower set. If the mixed material is compacted before this cutback material has evaporated, the material will continue to move around. So, I would suggest that it is well to have a pentrometer available to check yourselves once in a while and find out whether or not you are actually receiving the asphalt you are supposed to be receiving, and at the same time this will eliminate a lot of arguments with some driveway contractor or someone like that. He will say the asphalt is too hard or too soft. He never blames it on anything but the material.

In most asphalt plants today there are return lines from the asphalt tank to the asphalt bucket or meter. Some of the older asphalt plants that have been converted do not have them. For example, in one setup the asphalt comes from the bottom of the tank, goes up and over to the asphalt bucket or meter, and back on the top line. The reason for this is that in the tank the asphalt circulates continually, and a uniform temperature must be maintained.

As I go along, I am going to point out the importance of temperature in hot asphaltic concrete. You might say it is the basis for what happens out on the project, as to whether or not you are going to get good compaction which ultimately ends up in a good project.

Plant Stockpiles

In Figure 2 you will see our old friend, the stockpile. For the life of me I cannot understand why a quarry operator spends thousands of dollars putting in screens. He screens his aggregate to almost any size he wants, then he takes it out of the bins and puts it on the stockpile. All the coarse material rolls down to the outside and the fine material stays in the middle.

Then we have a crane operator who starts at the top and goes right down through the middle of the pile. Probably when the designing engineer came out he took his sample from the outside of the pile. He did not get a representative sample to start with, so he designs it on that basis, let's say. He has a certain surface area on which he is going to add asphalt. The surface area is small because he has coarser particles. So, the crane operator gets down to the middle of the stockpile, and when the

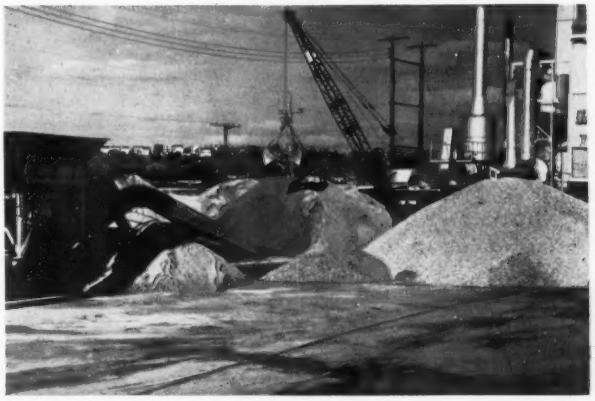


FIGURE 2

mix is made from this material he does not have enough asphalt to cover it. The result is that the road ravels and tears out.

Or, it can work the other way, and some of the slippery pavements are caused by just this. If the design has been set up on material from the fine part of the stockpile and the crane operator is charging coarse material into the plant, then the surface area is too small for the amount of asphalt designed and flushing will take place resulting in a slippery pavement.

After having been with the Pennsylvania Department of Highways, I know that stockpiles can be built that will not segregate. That is the secret of any design, whether it is rigid or flexible pavement, because actually all you are doing is taking large aggregate, filling the voids up with smaller size aggregate, and putting some ingredients in there (in this case asphalt) to hold it together. That is stated as simply as I can state it.

There is another reason why I think it should be attractive to you, and that is if you get a well designed mix and keep it that way, you will sell more aggregate to the producer than you will if you have a poorly designed mix with a lot of voids. Actually, the reason you are doing it is to fill the voids to the maximum amount with aggregate.

Another thing I would like to point out here is that this stockpile is not accentuated. This stockpile is not segregated now; however, more material added to it would cause segregation. I am talking about stockpiles that are mostly coned or stockpiles that somebody makes at the quarry by dropping the aggregate over a bank and all the coarse stone runs down along the side. Yes, there are some cases where they can be recombined pretty well, but this crane operator does not know anything about that. Nobody has ever told him.

The result is that unless he is told to move around the surface of the stockpile and to take it off in layers, such as you might say it was put on the pile, he will work instead in one spot. He does not know what effect that will have on the material coming out the other end of the plant. In other words, we are getting back to the old saying of years ago, that it went in one end of the plant white, and came out the other end of the plant black, and that is about all we knew about it.

The result is that in Pennsylvania they are very strict in the Highway Department about stockpiles. In many states they have specifications stating that the material at the so-called cold elevator must meet a certain gradation. Others do not seem to bother with gradings at the cold elevator. If the bituminous concrete producer realizes the importance of well graded materials, then it is not necessary for the Engineer to worry about cold gradings. Assuming everything else in the plant is working efficiently, an inspector can control his mix at this end of the plant.

If you have set up a design whereby you do not have the material there to start with, then of course you will get into trouble. For example, suppose we were using a 1 in. size aggregate, and our 1/2 in. screen is our control screen. Suppose we set it up for 62 per cent 1/2 in. material and we have only 55 per cent in there. We could not very well get it out. So, many states do propose to have a specification whereby it must meet, as they say, the grading requirements at the cold elevator.

I cannot actually impress upon you too strongly the necessity of good stockpiles, well graded materials, well particle shaped materials. There are some cases where our old friend the flat aggregate can be helped by design. However, if we are going to get a lot of segregation, then we have another strike against us to start with.

Start of Processing Material Through The Plant

Many plants are operated with a three compartment bin for proportioning the cold feed.

Today, if I were setting up a plant, I would want at least four cold bins, for this reason: The Corps of Engineers today is thinking about breaking down the aggregates into more sizes so that in their plant they can fill up the voids and know what size aggregates are in there. Many states are doing the same thing.

For example, if you are shy on 1/2 in. material in the mix, you can blend. This blending in stockpiles you know about, but I have yet to see a satisfactory way of blending material in a stockpile. You can pick a sample that will pass, and for every one you pick that will pass, you will find one that will not pass. You get the same thing when it goes through the plant.

They are requiring automatic feeds today to insure a uniform feed through the drier. This is a spot where, if the aggregates are running uniform in gradation, you do not have to bother the proportioning gates too much. When I say "uniform," they could be 7 per cent plus or minus the design screen on which you set it, or the design percentage on which you set your mix. If it runs outside that, there has to be an adjustment. I know somebody is thinking, "What's the difference? We are going to screen and separate it a little later on, anyhow." I will show you later why I think it should be taken care of here.

Another point I would like to make here is that in order to be assured of a continuous feed, it is well to keep your bins full at all times, so that you keep the weight on the material, forcing it down onto this automatic feed. In many cases today they are requiring vibrators on the bins, because "the man got tired and went out for a cup of coffee and didn't come back to push the sand or stone down, and we were shy of material in the hot bins!"

Dust Collecting System

There is one thing I want to call attention to and that is the dust collecting system. A producer at one plant told me that his dust collecting system has paid for itself, in that he does not have nearly as much machinery maintenance in his plant because he keeps it clean. Honestly, I must say you can walk into his plant with the suit you are wearing today, and you will have hardly any dust on it when you leave.

He collects dust at the back of the plant where the aggregate drops into the drier. The fan is a center draft fan which pulls the heat through, also pulling out the dust.

As we go on through the plant the same is true where the aggregate drops onto the screens, over the screens, and over the pug-mill. This system has worked excellently. A lot of it has been installed by his own plant workmen.

Drier

The man on the aggregate pile is an important person in the plant. The next man of importance in the plant is the one running the drier. Many plants think that the driers will take 60 or 70 tons an hour, or whatever the figure might happen to be. The drier will take only as much material as it can heat and dry. See Figure 3.

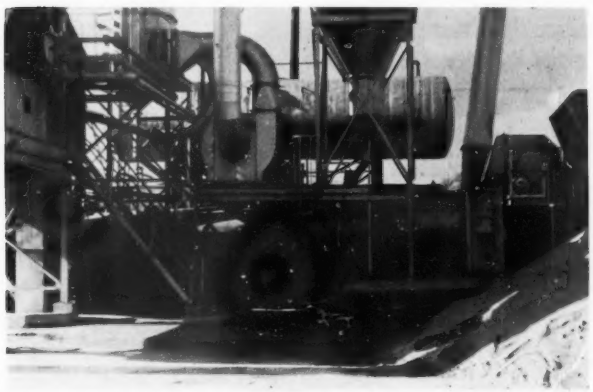


FIGURE 3

Usually a 60 ton an hour drier is set up on the basis of 2 or 3 per cent moisture in the aggregate. Again it depends on the aggregate. Some aggregates are porous and will take up moisture; other aggregates will dry very quickly. The thing I want to point out here mostly is that the aggregate itself controls the temperature of the mix, not the asphalt. The asphalt is put on in such a thin layer on each particle of aggregate that the second it comes in contact with the aggregate it assumes the temperature of that aggregate.

If you are heating aggregate for hot asphaltic concrete between 250 and 300 degrees, you will find that as long as your aggregate is dry the drier will dry 60 tons an hour if it is set up to do that. However, if the aggregate is wet, you have to cut down your feed in order to dry the aggregate and also to heat it. Increasing the heat to drive off moisture ofttimes results in driving the moisture into the aggregate. Many times the moisture that is being driven into the aggregate by overheating will not show up until you receive the material on the job, then it comes out of the aggregate and will strip the asphalt from the aggregate.

I say that the temperature of the aggregate should be within 15 degrees plus or minus of the temperature of the asphalt, and that the temperature of the asphalt should be based on the viscosity between 75 and 150 seconds of the asphalt that you are using.

That is rather technical, but it is not so hard. In other words, from your producer of asphalt you can secure a viscosity chart on his asphalt, and it will show you the best temperature to apply his asphalt is at 150 seconds. Let us take a hypothetical case. Between 75 and 150 seconds the best temperature for 85 to 100 penetration asphalt is probably 285 degrees. Then you vary the temperature of your aggregate as to the temperature you want to lay the material, and keep the asphalt at 285 degrees, and you can stay within that 250 to 300 degree range pretty well, which is a good laying temperature for hot asphaltic concrete in most sections of the country under good weather conditions.

However, once you start getting outside, up to, say, 400 degrees, what you are doing is cutting back the penetration of the asphalt. The minute it hits the aggregate it will not be burned, but will cut back the penetration. It also will thin out the coverage over the surface area which you have. Again, if you get it too cold you will get too much asphalt on it, and then we get back to slippery pavement again.

So, this man is highly important, because after a day or night of rain this man has a job. The con-

tractor should not expect to get 1,000 tons a day if he has had two or three days of rain, because the morning production is going to be cut down (if they are running the plant properly) because they cannot get it through the drier. If you do not get the moisture out of it, then you are going to have stripping of asphalt.

Consider the heating chamber. A lot of specifications throughout the country are still written today stating that the flame is not supposed to touch the material. It goes into the drier perhaps 2 ft. I see nothing that hurts the aggregate at all as far as the flame touching it at that time is concerned.

There are flights that pick up the material and bring it through the drier. The drier is set on a pitch, and the flights pick it up and take it through.

The aggregate drops down. Actually, you have no so-called flame coming in contact with the material. The aggregate is actually heated and dried by hot gases rather than by the flame itself. As the material is picked up at the top, it is dropped down and those hot gases go through it. You can understand what a tremendous amount of heat you can pull through there and heat your material.

The pyrometer in the particular case I have been referring to is located at the intake end of the drier, right at the cold elevator. It has a wire that runs down to the outlet end of the drier, or down near the hot elevator. Here the man can observe the temperature of his material and adjust the feed into the drier as is necessary to maintain temperature and moisture control.

Unless he watches this very closely, the man out on the job will be in trouble. I have seen it happen that in the morning, after a rainy session, the first load will come out at 300 degrees. The next couple of loads taken out will be down to 250 degrees because he has dropped it down too much. The 250 degree material probably should be rolled right away. We cannot roll the 300 degree material right away because it picks up on the rollers. The roller man is not going to run around the 300 degree material and roll the 250, and then come back and roll the 300. So, by the time we get to the 250 degree material we do not get the compaction on it that we should because of loss of heat in the material. The only thing you have in there for workability is heat. Unless it is rolled at the proper time, you will not arrive at the proper compaction.

There is a hot elevator going up to the screen. The material is deposited from the drier into a bucket elevator and carried to the screens. There is a return dust collecting system and there is a small butterfly which uniformly adds the material back into the hot elevator.

Can the dust be added back into the material? If the dust collected is uniform in grading, then I think it should be added back, provided there is not too much of it. I have seen plants that actually collected as much as four or five truckloads of dust a day. That would be too much to add back, and some of it would have to be wasted.

Uniformity of gradation means that if you have a large amount of 200 mesh material that you are collecting, then it should not be added back, because the pavement will become too stable and will crack.

Once again we have Old Man Voids. What you are trying to do with these small particles is to fill the voids in there. If you have material that is uniform, that will help to fill the voids, then it can be added back, yes; otherwise I would say no.

Plant Screens

Then we come to what I call the third important bottleneck in the plant—the screens, in this case a 4 deck screen. The plant can produce only as much as it can get over the screens, and only as much as it can screen efficiently. By feeding the drier too fast and overloading these screens, you are going to get into trouble, because you design your mix on the material from your bins. Suppose in bin No. 2 we found 10 per cent of the material passing the No. 6 screen or fine aggregate that should have been in bin No. 1. We make adjustments in our design to weigh out 10 per cent of the No. 6 material from bin No. 2 and reduce the amount of No. 6 material in bin No. 1, so as not to overload the mix with fines. The mix ran along for awhile and looked good, suddenly we find the mix too fine, so we check our bins. Instead of 10 per cent No. 6 material in bin No. 2, we find 25 per cent No. 6, and in bin No. 3 another 10 per cent of No. 6 material where before there was no No. 6 material. This was caused by overloading the screens and has changed our design completely. After the design has been set up, the screen efficiency must remain uniform. This is generally controlled by the feed at the cold elevator.

Again I talk about uniformity, and what these screens can do for you. If you are running material over the screens and are getting 30 per cent screen efficiency, and if it is uniform, it is all right, because you can account for it in your design. However, if you are running over the screens and getting 10 per cent screen efficiency one time, and 50 or 60 per cent screen efficiency the next time, then you are not going to end up with an asphaltic concrete design that is very good.

In many places they specify screen efficiency, and it is not exactly the way the screen people or cloth people talk about screen efficiency. In Pennsylvania, for example, they have a 15 per cent plus or minus screen efficiency, and they break on the number of each screen. They do not care what size screens you put in your plant, they base it on the laboratory screens—No. 8, which means that in bin No. 1, where the No. 8 material is supposed to go, you might put a 1/8 in. screen on it, but you may not have more than 15 per cent retained on the No. 8 screen in that bin. In bin No. 2 you may not have more than 15 per cent passing the No. 8 screen, or more than 15 per cent retained on the 1/2 in. screen. On that bin you might use, depending on the particle shape of the aggregate, a 9/16 in. or 5/8 in. screen. On bin No. 3 they would not permit you to have more than 15 per cent passing the 1/2 in., nor of course any material retained on the 1 1/2 in., which is the top screen. That is what we mean by screen efficiency.

What does it do to you? After you have set up your design, you are basing anything that you have in that plant on the idea that you are going to weigh it out from each of these bins. In other words, if we could take the aggregate and split it up upon a passing-retaining basis for each screen we would like to use—going back again to our voids —which would fill our voids, then we can weigh out each individual size of the material we want.

A gentleman said to me yesterday, "I don't see why they don't tighten the specifications." They are doing it. The Army Engineers just recently tightened them. They are getting more sizes so that they can do that.

That is what some of these highway departments are coming to. I agree that they are going to have to pay for it, but we are arriving at something that is going to give us a better pavement. It can be done in a 3 and 4 bin plant, providing we first have the material in the stockpiles to do it with; secondly, providing we do not have a lot of segregation; thirdly, that we have a well shaped material; and, fourthly, that we have controlled screen efficiency.

The strength in asphaltic concrete and any other surfacing material is dependent upon the aggregate that you use, the interlocking of those aggregates. Again, I repeat, the only thing we do is to hold it together with asphalt.

Then there is the filler bin which brings the material up to the weigh hopper. This again is part of the dust collecting system, and I might add, this bin is provided with safety ladders. I have heard you talk about safety. At an asphalt plant I think those things are highly important.

Hot Bins

Consider the 4 bin plant. There is an oversize chute for oversize materials that might get into the aggregate; these are then scalped out by a scalping screen.

The fine aggregate goes in bin No. 1. Consider that material that will pass a No. 6, 8, or 10 sieve depending on the specification you are working with; in bin No. 2, that material that would be retained on a No. 6, 8, or 10 and pass a 1/4 in. or 3/8 in. depending on the specification you are working with; in bin No. 3, that material that would be retained on the 1/4 in. or 3/8 in. and pass a 1/2 in. depending on the design; and in bin No. 4, that material that would be retained on the 1/2 in. and pass the top size screen, say 1 1/2 in. in this case.

I cannot impress upon you enough the importance of the uniformity of the feed back at the cold elevator and the grading of the aggregates as to the control of these bins. If the grading of the aggregate, say on the 1/2 in. material, were to change from 45 per cent to 25 per cent, then bin No. 3 would become empty in time and bin No. 4 would be overloaded. The material should never go above the overflow openings, and the contents in each bin should remain uniform.

Secondly, the man who is weighing out the material seems to think he is doing his boss a favor. He pulls the required amount of material from the first bin, he pulls the required amount of material from the second bin, and in bin No. 3 what does he find? He is supposed to take 500 lb from this bin, and he has only 200 lb in it. "Well, I can't hold up production, so I'll go over and take it from bin No. 4." So he does that. Is he doing you a favor?

I don't think he is. Your best advertisement is a good product—a good job. If you give him good material, you yourselves will have done your part of the work. If you do not, then you are to blame. Here is where a lot of it happens.

Remember that from these bins comes the material on which you run gradings, or on which the designing engineer runs gradings to set up his design. He cannot change those designs every fifteen minutes.

Let me repeat again that the basis of a good asphaltic concrete design is controlled in these bins and is dependent on the uniformity of the aggregate as it goes into the mix, and on the screening ability of the plant to screen uniformly and within certain ranges. When I say "within certain ranges" I do not say you have to set a 15 per cent screen efficiency.

Again, if you have a 30 per cent screen efficiency, and if it stays there all the time, you are just as well off, because you can compensate for it here. If you are getting 30 per cent in bin No. 1 over into bins No. 2 and No. 3, then you can compensate for it in the design, but you cannot do anything about it if you get 30 per cent one place one time and the next time, because they are not feeding as fast, and let us say 20 per cent of that goes into bin No. 1, and you have only 5 per cent in these other two bins, then your design is off and you are in trouble.

The plant I am speaking about has a heating device placed on the bins. I think it is a good idea, whenever you are mixing hot asphaltic concrete, particularly to know whether or not or how long you can leave the material in your bins. The reason for that is again the only workability that you have out on the project, as far as compaction is concerned, is the heat in it.

So, if this material is cooled down to a point, because of delays or something like that, again your best advertisement is a good product. Draw your bins and get hot material up there.

The designing engineer takes his samples at the bins and designs on the basis of the material in those particular bins. Leading from the cold elevator up to this point, I hope I have shown you what can happen to you as far as these samples are concerned. I would insist at all times on any inspection force taking large samples of material from these bins, also that the plant has run a sufficient amount of material into the bins to simulate just what your production is going to be when you actually go to do the job.

This design is set up prior to the time the job starts. If you get only a little bit in the bins, it is not indicative of what you will actually get when you are in full production.

One thing I would like to point out here is that many plant manufacturers today realize the importance of getting adequate samples, and are doing something about it. Some of our older plants which we still have around do not have a very good means of selecting samples. There are a lot of so-called Rube Goldberg ideas around the country, whereby people have set up different devices for sampling.

For example, running a track under the bins so they can set a pan under it that will fit the entire outlet ends of the bins, so that you do not get any sloughing over onto the pans or anything like that. Be sure that when the sample is taken, the sample container covers the entire outlet end of the bin. Take large samples.

Weight Hopper Over Mixer

The weight hopper is directly over the pug-mill. The material is weighed and deposited into the pug-mill.

I said before, and I will repeat once more: Take the lever man who thinks he is doing you a favor. He gets the right amount out of bin No. 1. He gets the right amount out of bin No. 2. He does not get the right amount out of bin No. 3, so he goes to bin No. 4 and takes it all out of there. He is not doing you a favor, and he is not doing asphalt any favor, either.

The Howe scales are those on which all the material is weighed. The pointers should be set up on the scales. After all, the man up there is important. After you have gone to all the trouble to give him well graded aggregates, and you have gone to the trouble of taking it through the plant correctly, if he does not weigh it out correctly you still end up with a poorly designed material.

Asphalt Meter and Bucket

One particular plant with which I am familiar proportions its asphalt through a meter. These meters are very delicate, and there should be a take-off pipe some place between the meter and the pug-mill, so that the meter may be checked.

In the case of asphalt buckets, I would like to say they should be checked at least once a day with weights, but they should be checked more than that the first thing in the morning; the first two hours of operation, let us say, they should be counterbalanced after every truckload of material.

The reason I say that is this: You get an accumulation on the sides of the buckets which cools off overnight. In the morning, when you start to weigh out material the heat of the new asphalt will loosen some of that which has accumulated on the sides and bottom of the bucket. This will change the tare weight of the bucket.

Most designing engineers today are trying to get enough asphalt in there so they have reached the peak. In other words, they have put just as much asphalt in there as it will possibly take. Any additional asphalt in there is going to cause flushing, with the result that there might be just enough asphalt on the side of the bucket to cause some flush spots. It takes only a second to kick the balance beam back and to balance the bucket. I have found as much as 7 or 8 lb difference from 6 a.m. to 8 a.m.

The Air Corps Engineers and Army Engineers require timers on their plants today. The time of the mix is produced mechanically. In other words, it is controlled mechanically. Many states have a specification whereby they call for dry mixing periods of 15 seconds, which are controlled by the timer.

Mixer

The pug-mill, I think, is another important feature. In many cases you will find that a paddle is broken. One paddle broken will not hurt too much, but if you have two of them broken it will hurt a lot. It is difficult to shut the plants down and try to fix a paddle when you have been running for 3 or 4 hours, because of the heat in there. It takes awhile for them to cool off. I do not think one broken paddle will hurt anything; but when you get a paddle broken off and another broken off right next to it, then it should be shut down and the paddles replaced, because you will have a gap there whereby the material cannot be picked up.

Something else we have found in Pennsylvania is that if you take the end paddles and reverse them you can get a boxing action. I believe, although I am not sure, that some of the manufacturers are doing that today. In many cases we had material right on a peak, and we found that by reversing these paddles on the ends, we got what they call a boxing action, or a little better mix.

Again I would like to say that if you have a 2 ton box, do not overload it more than 15 per cent, and do not underload it more than 20 per cent above the rated capacity of the mixer. The tips of the paddles at the peak of the turn should be about 2 in. or 3 in. outside of the mix material, and if you overload them they will not be, and you will not get good mixing. If you underload the mixer, the material will lay around the shaft and good mixing will not result.

I have seen mixes that were improperly mixed because of overloading and underloading. Somebody will say, "How do you know that? How can you tell?" You cannot actually tell except by taking the material and running tests on it. You will find that the material then will show excessive asphalts on the fines, and probably low-content asphalts on the coarse aggregates. It has to be separated.

The material is then dropped down into the truck and is ready for the job.

Plant Testing Laboratory

In talking about controls in plants, such as we have done here, I think each producer should have a small, equipped laboratory to run samples of material so that he can tell his customer what he is doing.

If you get into arguments with roadway men, federal or Bureau men—most of them require you to have a laboratory today. In this highway business, which is so highly important, you can get into many arguments when there is a failure and the material is no good. Nothing else is ever wrong—just the fault of the material. Then you have a way of proving to those people that the material was all right, and it was in the use of the material that the difficulty took place.

These laboratories do not cost too much, and for the amount of money that you have invested in the rest of your plant or in other parts of your plant, this is a minor expense and will serve a good end.

In closing, any hot asphaltic concrete plant that is controlled in the manner we have just discussed cannot help but produce a high type asphaltic concrete.

Designing Flexible Pavements for Strength—Not Thickness[1]

By RAYMOND C. HERNER
Chief, Airport Division
Civil Aeronautics Administration
Indianapolis, Ind.

Engineering design of a structure is primarily a process of balancing load stresses, determined by measurement or theoretical analysis, against the strength of materials, determined by laboratory tests. In some instances the relationship between the two can be expressed in precise mathematical terms on the basis of accepted structural theory; in others, the indicated relationship is an empirical one.

At some point during the design process we insert a multiplying factor called a "factor of safety." The size of this factor generally varies with the relative importance of the structure and the possible disastrous consequences of its failure. It also depends upon any uncertainties regarding the magnitude of load stresses or the strength value of the structural material. For the latter reason the factor of safety has been dubbed "the factor of ignorance" by some of our more irreverent and cynical engineering brethren. The important point is that we can design and build more economical structures, without any real sacrifice in safety, if we will only utilize new knowledge of materials as it becomes available.

Although a pavement has many functions, we consider it primarily as a load-supporting structure which distributes the concentrated vehicle load over a large area of subgrade, so that subgrade stress and deformation will be held within safe limits. Its efficiency in this respect depends upon the thickness and structural qualities of the pavement section.

It is accepted practice to vary the cross-sectional dimensions of a beam, slab, or other structural element, according to the strength of the material from which it is constructed. We certainly would not replace an 8 by 12 in. wooden beam with a steel beam of the same dimensions. We consider it entirely reasonable to base the dimensions of a concrete beam or floor slab upon the measured strengths of the concrete and steel from which it will be built. In flexible paving design, however, it still is common practice to designate the pavement thickness for a given load and subgrade condition without any regard for the quality and physical characteristics of the materials to be used.

True, we have specifications which set up minimum requirements for surface, base course, and sub-base materials. These requirements are based on the prevention of shear failure within the pavement itself. Adherence to these specifications will generally produce an acceptable pavement, as the thickness design for subgrade protection is based upon experience with the poorest material allowed by the specifications.

The materials available for use may vary widely, however, in their shearing strength and in their capacity for load distribution. Under most present design methods no reduction in total pavement thickness is allowed for use of the higher quality materials, even though the same degree of subgrade protection is furnished. If alternate designs were based on equal *strength* rather than equal *thickness,* the better materials would be competitive in some areas where they are now forced out of competition by cheaper materials of lower quality.

In view of the strong promotional forces at work among producers of construction materials, one can hardly blame the design engineer for avoiding alternate designs of flexible pavement unless he has sound factual information upon which to base his decisions. Indications of the importance of such information are found in the early work of A. T. Goldbeck, Engineering Director of the National Crushed Stone Association, and others, but the literature on the subject is still very skimpy, and some of the reports from field studies have been either negative or inconclusive. We now have available a new unbiased source of authoritative and comprehensive test data in the operation of the Load Transmission Project at the CAA Technical Development and Evaluation Center in Indianapolis. The remainder of this paper will be devoted to a description of this project and the results obtained from it thus far.

Apparatus and Test Methods

The load transmission apparatus is a large scale loading and testing device by which full size flexible pavement sections can be tested for structural action

[1] Presented at the 39th Annual Convention of the National Crushed Stone Association, Conrad Hilton, Chicago, Illinois, February 20-22, 1956

under carefully controlled laboratory conditions. The natural subgrade is replaced by an artificial subgrade of 3,600 small steel plates, each supported by a calibrated steel spring. This provides a continuous flexible loading platform 10 ft square, upon which the pavement section is constructed. The sides are confined by wooden bulkheads. Provisions are made to measure the deflection of each plunger under any loading condition. Figure 1 is a schematic sketch of the apparatus, and Figure 2 is a photograph of the artificial subgrade with a cut-away pavement section in place and an airplane tire in loading position.

When a load is applied to the pavement surface the individual segments of the subgrade are depressed in varying amounts, dependent upon the vertical loads transmitted to them through the pavement. For simple loadings the maximum stress and deflection occur under the center of load, and the intensity distribution over the subgrade varies in an orderly fashion as shown in Figure 3.

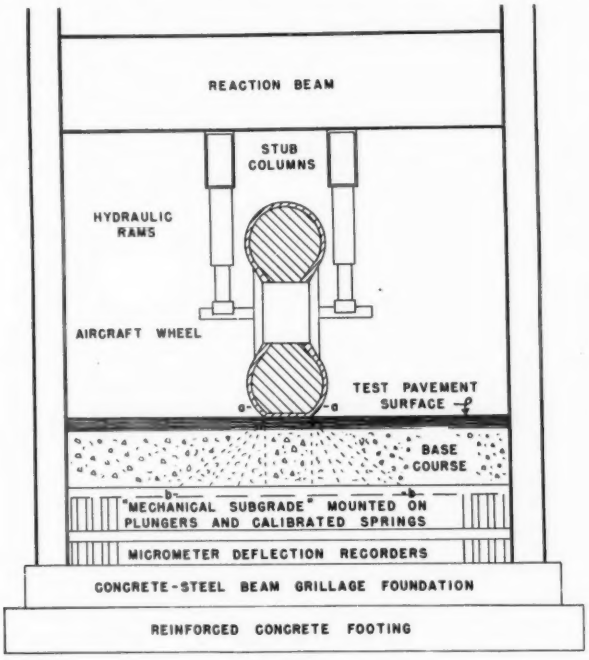


FIGURE 1

Load Transmission Testing Rig

A wheel load applied to the pavement surface over an area a—a is transmitted and distributed thru the surface and base course. This produces varying pressures and deflections over a larger area b—b on the subgrade. In this test the natural subgrade is replaced by a "mechanical subgrade" or flooring composed of 3,600 small steel plates. These are mounted on plungers and calibrated springs in such a manner as to simulate a subgrade of the desired strength and to permit measurement of the unit pressures transmitted to the subgrade.

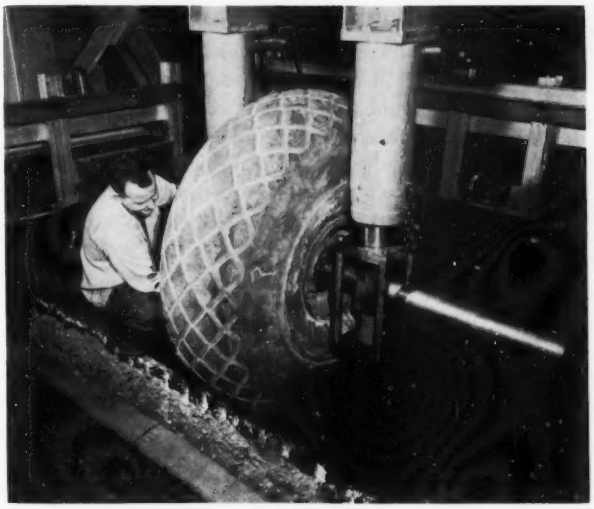


FIGURE 2

General View—Load Transmission Apparatus

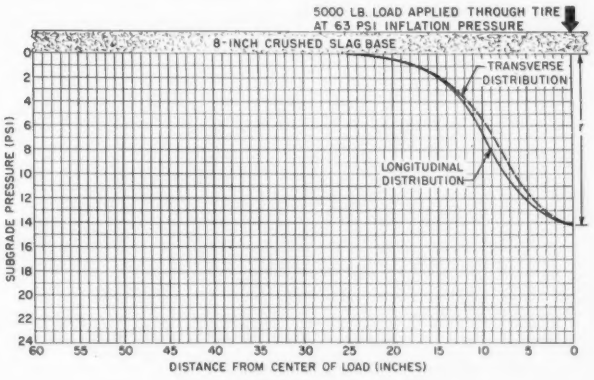


FIGURE 3

Typical Pressure Distribution Pattern

Had the pavement been more effective in distributing the applied load—due to use of a better material or a greater thickness of the same material —the load would have been spread over a larger area of subgrade and the maximum stress under the center of the load would have been less. This maximum stress or reaction may be used as a convenient index of pavement effectiveness under given loading conditions. Although the reaction is a function of many variables, this paper is concerned only with the comparative effect of pavement quality versus pavement thickness.

Description of Materials Tested

Loading tests have been run on pavement sections constructed from a large number of different materials. The selected materials varied widely in gradation, particle shape, and cohesive binder, making it possible to study the relative effect and importance of each of these qualities. Most of the pavement sections used in these earlier tests were constructed of the same material for their entire depth in order to facilitate comparisons.

Although it has not been feasible to run a complete series of tests on each material, there is enough test information available now to provide some interesting comparisons. The following brief description of the materials used should be helpful in analyzing the differences found.

Normal Gravel

In a large number of the tests we used a partially crushed pit gravel, reasonably well graded, with practically 100 per cent passing the 1 in. sieve and about 10 per cent washed through the No. 200 sieve. This gravel is typical of that available from many sources, and it was chosen as the standard material against which others were rated. This proved to be rather an unfortunate choice because of wide variation in physical characteristics of the "standard" material. Consequently, some discrimination is required in selecting for comparative purposes only those gravel sections which were reasonably normal in composition and behavior. In the figures and discussion which follow, the descriptive term "weak" has been applied to a couple of gravel sections which definitely were below average.

Clay-Gravel

In addition to those gravel sections which were weak from natural or accidental causes, a few were made weak intentionally by addition of higher quantities of fines and moisture. These were intended to represent the poorer gravels often used for sub-base —and sometimes allowed in base course construction.

Sand

A relatively clean concrete sand was used to represent the fine-grained non-cohesive materials. It would pass some sub-base specifications.

Crushed Limestone

The crushed limestone was well graded, with a top size of 1 1/2 in. and about 10 per cent passing the No. 200 sieve by washing. There was sufficient binder and particle interlock to provide high stability even when unconfined. It was typical of high quality, dense-graded crushed stone bases.

Crushed Slag

The crushed slag was gap-graded, with 1 1/2 in. maximum size and no cohesion. A macadam type construction was used, the fines being vibrated into the voids of the coarser material.

Asphaltic Concrete

Only a few asphaltic concrete sections have been tested. These consisted of a rather open-graded binder-course mixture using about 5 per cent of low penetration asphalt. The aggregate was a mixture of partially crushed gravel and sand. The mixture was obtained from commercial hot mix plants in regular production for street and highway work.

Effect of Pavement Quality on Subgrade Stresses

Figure 4 gives you some idea of the importance of pavement quality in reducing the vertical stresses transmitted to the subgrade. Each curve shows the measured distribution of subgrade stress, along the longitudinal axis of the loading tire, for a different test pavement. In each case the applied load is 20,000 lb, the tire inflation pressure is 100 psi, and the pavement thickness is 24 in.

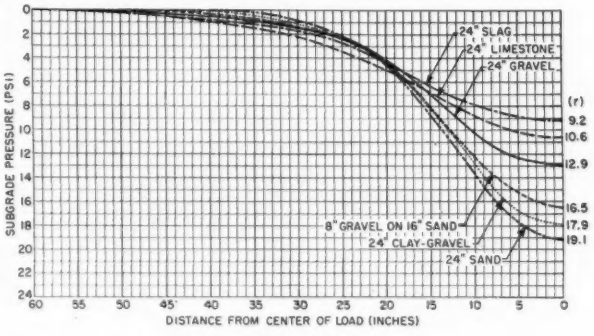


FIGURE 4

Longitudinal Load Distribution Pattern for Various Base Course Material—24 In. Thickness, 20 KIP Load, 100 PSI Inflation Pressure

The sand section is the least effective, and the clay-gravel is little better. The crushed slag and limestone, with sharp angular particles, show up well under the high degree of confinement in the 24 in. depth of pavement. In fact, the maximum subgrade pressure under these sections is little more than half that found under the less effective materials. The normal gravel is intermediate in effectiveness, and the composite gravel-and-sand section

very logically falls between the curves for these two materials used separately.

Similar information from 16 in. pavement sections is given in Figure 5. A 10,000 lb load is used for these comparisons. Here again, the two crushed materials are the most effective.

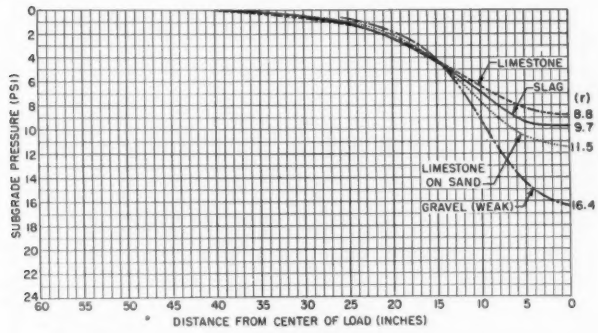


FIGURE 5

Longitudinal Load Distribution Pattern for Various Base Course Materials—16 In. Thickness, 10 KIP Load, 100 PSI Inflation Pressure

The differences found in 8 in. pavements (Figure 6) are not so striking, as the thin section does not provide enough confinement to bring out the potential effectiveness of the crushed materials. Even here, however, the superiority of the crushed stone, which combines moderate cohesion with good particle interlock, is measurable. The slag section, which lacks cohesion, is no more effective than the normal gravel when used in this thin section without any cover.

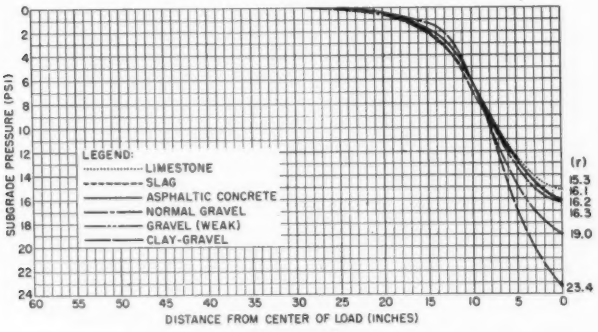


FIGURE 6

Longitudinal Load Distribution Pattern for Various Base Course Materials—8 In. Thickness, 5 KIP Load, 100 PSI Inflation Pressure

Performance of the 8 in. asphaltic concrete section was no better than that of the same thickness of gravel, and not quite so good as that of crushed stone. It should be noted, however, that the comparative performance of asphaltic concrete should be much better under loads of short duration where the viscous nature of the material would be an important factor.

Economic Significance of Designing on a Strength Basis

The data from the load transmission tests can be used in setting up designs which are really equivalent from a strength standpoint. Figure 7 is a very striking illustration of results plotted directly from test data. Here are results from two pavements, each supporting the same load (20,000 lb) with the same tire inflation pressure (100 psi) and yielding almost identical stress patterns on the subgrade. One pavement is of conventional construction, with an 8 in. gravel base on a 16 in. sand sub-base—a total thickness of 24 in. The second pavement, composed of crushed stone for its entire depth, is only 16 in. thick but is doing the same job equally well.

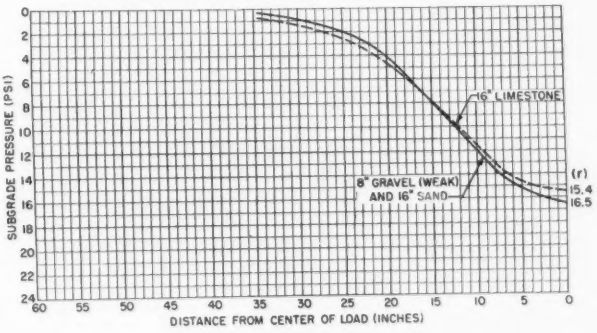


FIGURE 7

Quality vs. Thickness for Equal Load Distribution—20 KIP Load, 100 PSI Tire Pressure

Figure 8 shows equivalent thicknesses for some possible pavement sections designed to support a 15,000 lb load on a weak subgrade, the subgrade pressure to be limited to 12 psi. Estimated cost per square yard for each section is based on the delivered price of material at Indianapolis plus an estimated cost for placing. These figures are intended only for purposes of illustration.

Sand is so cheap in this area, being a plentiful by-product of gravel production, that a composite section using sand as a sub-base should be the cheapest construction. The reduction in thickness for the crushed materials does put them in a more competitive position than they otherwise would be. In many areas this difference would be sufficient to tip the balance in favor of the higher quality materials. The important thing is that we

now are getting to a point where the paving engineer can prepare competitive designs that are really equivalent from the standpoint of subgrade protection. The cheapest bid and the best bid then become one and the same thing. Competition among materials has not been eliminated; it simply has been placed on an equitable basis.

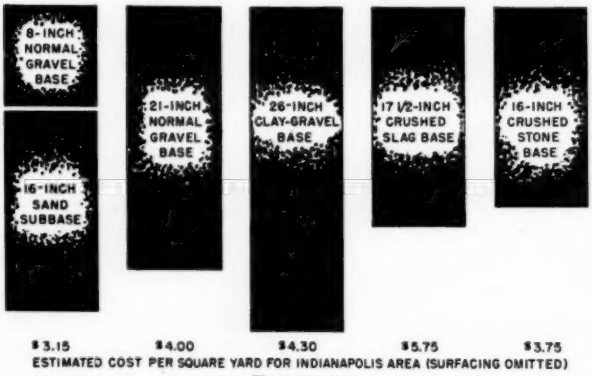


FIGURE 8

Correlation of Load Transmission and Triaxial Test Results

The figures presented thus far are valuable indications of the differences in performance to be expected from various types of materials. Strictly speaking, of course, these figures are applicable only to the specific materials tested. We all know that there may be wide ranges in quality within a general class of materials. Comparative designs for a given project, therefore, should be based on tests of representative samples of the materials actually proposed for use. This would be an impractical requirement if it involved use of the load transmission testing apparatus for each design problem as there is only one set of such equipment in existence and the tests themselves are expensive and time consuming.

The obvious remedy for this situation is to find a comparatively simple auxiliary test to measure the physical factor most readily related to pavement performance. Our tests to date indicate good correlation between the load transmission test and the triaxial test. The latter is a compression type test wherein the sides of the specimen are confined laterally by fluid pressure while the specimen is compressed longitudinally. Although the applied load is compressive, the specimen actually fails in shear. The confining pressure, somewhat analogous to confinement of the material in a pavement structure, increases the apparent strength of granular materials which may be lacking in cohesion but have a high coefficient of internal friction.

In evaluating materials for possible use, they are tested triaxially at lateral pressures corresponding to various depths—and subsequent degrees of confinement—in the pavement. Typical test results from various materials have been summarized in Figure 9. Performance of the pavement structure is predictable directly from these test results.

Details of the testing and evaluation procedure are beyond the scope of this paper and may be obtained from other reports.

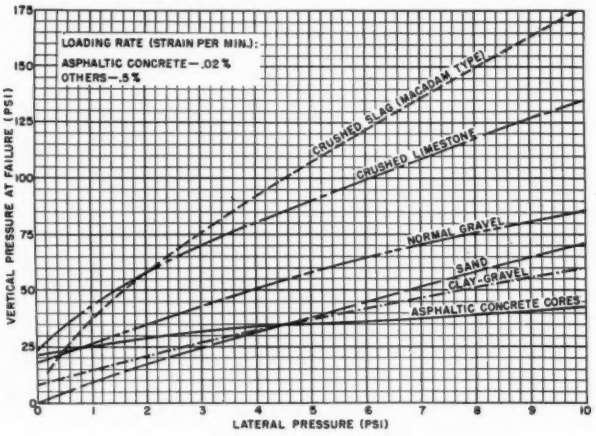


FIGURE 9

Triaxial Test Data—Relationship of Principal Stresses

Some highway departments, universities, and commercial testing laboratories already have triaxial testing equipment. Those which do not can obtain it at reasonable cost.

Conclusion

Although there is much yet to be done in the load transmission test program, it already has served to focus attention on the important question of quality versus depth in the design of flexible pavements. We have shown that there are substantial differences in the performance of paving materials, and that the qualities affecting performance can be measured and evaluated. This is an encouraging start. When the work is finally completed, and design engineers have learned to use this new knowledge, the general public will benefit from the reduced "factor of ignorance" in flexible paving design. Producers of the better materials will be benefited also when we compare designs on the basis of strength—not thickness.

Manufacturers Division
National Crushed Stone Association

•

These associate members are morally and financially aiding the Association in its efforts to protect and advance the interests of the crushed stone industry. Please give them favorable consideration whenever possible.

•

Allis-Chalmers Mfg. Co.
Milwaukee 1, Wis.
Crushing, Screening, Washing, Grinding, Cement Machinery; Motors; Texrope Drives. Centrifugal Pumps; Air Compressors; Hauling Equipment; Engines; Tractors

American Cyanamid Co.
Explosives Department
30 Rockefeller Plaza, New York 20, N. Y.
Explosives and Blasting Supplies

American Manganese Steel Division
American Brake Shoe Co.
155 North Wacker Drive, Chicago 6, Ill.
Manganese and Alloy Steel Castings, Power Shovel Dippers, Material Handling Pumps, Reclamation and Hard-Facing Welding Materials

American Pulverizer Co.
1249 Macklind Ave., St. Louis 10, Mo.
Manufacturers of Ring Crushers and Hammermills for Primary and Secondary Crushing and Laboratory Sizes

American Steel & Wire Division
United States Steel Corp.
Rockefeller Bldg., 614 Superior Ave., N. W., Cleveland 13, Ohio
Wire Rope, Aerial Wire Rope Tramways, Electrical Wires and Cables, Welded Wire Fabric, Concrete Reinforcing, Wire Nails, Fencing, Netting

Aquadyne Corp.
89 Terminal Ave., Clark, N. J.
Dust Control Systems, Truck Bed Separating Agent

Atlas Powder Co.
Wilmington 99, Del.
Industrial Explosives and Blasting Supplies

Bacon-Greene & Milroy
29 Washington Ave., Hamden 14, Conn.
"Farrel-Bacon" Jaw Crushers for Primary and Secondary Operations, Conveyors, Elevators, Rolls, Screens

Baldwin-Lima-Hamilton Corp.
Construction Equipment Division
South Main St., Lima, Ohio
Power Shovels, Draglines, Cranes, Bins, Conveyors and Idlers, Crushers and Pulverizers, Feeders, Plants—Crushing and Portable, Washing Equipment, Asphalt Plants, Dust Control Equipment

Barber-Greene Co.
400 North Highland Ave., Aurora, Ill.
Portable and Permanent Belt Conveyors, Belt Conveyor Idlers, Bucket Loaders, Asphalt Mixing Plants and Finishers, Bucket Elevators, Screens

Birdsboro-Buchanan Crusher Dept.
Birdsboro Steel Foundry and Machine Co.
1941 Furnace St., Birdsboro, Pa.
Primary and Secondary Crushers and Rolls

Boston Woven Hose & Rubber Co.
P. O. Box 1071, Boston 3, Mass.
Conveyor, Elevator, and Transmission Belts, V-Belts; Sand Blast, Water, Steam, Air, Suction Hoses

Brunner & Lay Rock Bit of Asheville, Inc.
P. O. Box 5235, Asheville, N. C.
Tungsten Carbide Detachable Bits, "Rock Bit" Drill Steel Inlaid with Tungsten Carbide, Carbon Hollow Drill Steel, Alloy Hollow Drill Steel

Bucyrus-Erie Co.
South Milwaukee, Wis.
Excavating, Drilling, and Material Handling Equipment

Buda Division
Allis-Chalmers Mfg. Co.
Harvey, Ill.
Diesel and Gasoline Engines; Material Handling Equipment; Lifting Jacks; Earth Drills and Maintenance of Way Equipment

Canadian Industries Ltd.
P. O. Box 10, Montreal, Que., Canada
Commercial Explosives and Blasting Accessories

Manufacturers Division – National Crushed Stone Association

(continued)

Cape Ann Anchor & Forge Co.
P. O. Box 360, Gloucester, Mass.
"Cape Ann" Forged Steel Drop Balls

Caterpillar Tractor Co.
Peoria 8, Ill.
Track-Type Tractors, Bulldozers, Earthmoving Scrapers, Motor Graders, Heavy-Duty Off-Road Hauling Units, Diesel Engines, Diesel Electric Generating Sets, Front End Shovels, Wheel-Type Tractors

Chain Belt Co.
P. O. Box 2022, Milwaukee 1, Wis.
Rex Conveyors, Elevators, Feeders, Idlers, Elevator Buckets, Drive and Conveyor Chains, Sprockets, Bearings, Pillow Blocks, Power Transmission Equipment, Portable Self-Priming Pumps, Concrete Mixers, Iron Castings, Clutches

Clark Equipment Co.
Construction Machinery Division
P. O. Box 599, Benton Harbor, Mich.
Truck and Crawler Excavator-Cranes; Tractor Shovels; Turbo-Dozers

Continental Gin Co.
Industrial Division
4500 Fifth Ave., S., Birmingham 2, Ala.
Conveyors—Belt, Screw, Flight, and Underground Mine; Elevators—Bucket and Screw; Feeders—Apron, Belt, Reciprocating, Table, and Screw; Drives—V-Belts, Chains and Sprockets, Gears and Speed Reducers

Contractors and Engineers Magazine
470 Fourth Ave., New York 16, N. Y.
Magazine of Modern Construction

Cross Engineering Co.
P. O. Box 507, Carbondale, Pa.
Cross Perforated Steel Segments, Sections, Decks, for Vibrating, Shaking, Revolving, and Other Types of Screening Equipment

Cummins Engine Co., Inc.
Fifth and Union Sts., Columbus, Ind.
Lightweight Highspeed Diesel Engines (60-600 Hp.) for: On-Highway Trucks, Off-Highway Trucks, Buses, Tractors, Earthmovers, Shovels, Cranes, Industrial and Switcher Locomotives, Air Compressors, Logging Yarders and Loaders, Oil Well Drilling Rigs, Centrifugal Pumps, Generator Sets and Power Units, Work Boats and Pleasure Craft

Dart Truck Co.
2623 Oak St., Kansas City 8, Mo.
Off-Highway Trucks—End, Side, Bottom Dumps

Deister Machine Co.
1933 East Wayne St., Fort Wayne 4, Ind.
Deister Vibrating Screens, Classifiers, Washing Equipment

Detroit Diesel Engine Division
General Motors Corp.
13400 West Outer Drive, Detroit 28, Mich.
Light Weight, Compact 2 Cycle Diesel Engines and "Package Power" Units for All Classes of Service

Diamond Iron Works
Division Goodman Manufacturing Co.
Halsted Street & 48th Place, Chicago 9, Ill.
Jaw and Roll Crushers; Vibrator, Revolving, and Scrubber Screens; Drag Washers; Bucket Elevators; Belt Conveyors; Bins; Apron and Plate Feeders; Portable Gravel and Rock Crushing, Screening, and Washing Plants; Stationary Crushing, Screening, and Washing Plants; Hammermills

Drill Carrier Corp.
1701 Shenandoah Ave., N. W., Roanoke, Va.
"Air-Trac" Drill Carrier

Du Pont, E. I., de Nemours & Co.
Wilmington 98, Del.
Explosives and Blasting Supplies

Dustex Corp.
1758 Walden Ave., Buffalo 25, N. Y.
Dust Collecting Equipment; Dust Control Systems

Eagle Crusher Co., Inc.
900 Harding Way East, Galion, Ohio
Crushers

Eagle Iron Works
129 Holcomb Ave., Des Moines 13, Iowa
Fine Material Screw Washers — Classifiers — Dehydrators; Coarse Material Screw and Log Washers — Dewaterers; Water Scalping and Fine Material Settling Tanks; Drop Balls — Ni-Hard and Semi-Steel; "Swintek" Screen Chain Cutter Dredging Ladders

Easton Car & Construction Co.
Easton, Pa.
Off-Highway Transportation: Dump Trailers, Truck Bodies, and Cars for Mines, Quarries, and Earth Moving Projects

Electric Steel Foundry Co.
2141 N. W. 25th Ave., Portland 10, Ore.
Dragline Buckets, Shovel Dippers, Bucket Teeth, Crusher Wearing Parts, Cutting Edges and End Bits

Ensign-Bickford Co.
Simsbury, Conn.
Primacord-Bickford Detonating Fuse and Safety Fuse

Manufacturers Division – National Crushed Stone Association
(continued)

Euclid Division
General Motors Corp.
1361 Chardon Road, Cleveland 17, Ohio
Heavy-Duty Trucks and Dump Trailers for "Off-Highway" Hauls, Loaders for Earth Excavation, Single and Twin Engine Earth Moving Scrapers, Crawler Tractors

Frog, Switch & Mfg. Co.
Manganese Steel Department
Carlisle, Pa.
"Indian Brand" Manganese Steel Castings for all Types of Jaw, Gyratory, and Pulverizing Crushers; Dippers, Teeth, Treads, and Other Parts for Power Excavating Equipment; and Other Miscellaneous Manganese Steel Castings. Manufacturers and Fabricators of Railroad and Mine Frogs, Switches, and Crossings

General Electric Co.
1 River Road, Schenectady 5, N. Y.
Electric Motors, Controls, Locomotives, Welding Equipment, Coordinated Electric Drives for: Shovels, Drag Lines, Conveyors, Hoists, Cranes, Crushers, Screens, Etc.; Coordinated Power Generating and Distributing Systems Including Generators, Switchgear, Transformers, Cable, Cable Skids, Load Center Substations

Gill Rock Drill Co.
Lebanon, Pa.
Well Drill Tools and Supplies

Goodyear Tire & Rubber Co., Inc.
Akron 16, Ohio
Airfoam; Industrial Rubber Products—Belting (Conveyor, Elevator, Transmission), Hose (Air, Water, Steam, Suction, Miscellaneous); Chute Lining (Rubber); Rims (Truck and Tractor); Storage Batteries (Automobile, Truck, Tractor); Tires (Automobile, Truck, Off-the-Road); Tubes (Automobile, Truck, Off-the-Road, LifeGuard, Safety Tubes, Puncture Seal Tubes)

Gruendler Crusher and Pulverizer Co.
2915 North Market St., St. Louis 6, Mo.
Rock and Gravel Crushing, Screening and Washing Plants, Jaw Crushers, Roll Crushers, Hammermills, Lime Pulverizers

Gulf Oil Corp.
Gulf Refining Co.
Gulf Bldg., Pittsburgh 19, Pa.
Lubricating Oils, Greases, Gasoline and Diesel Fuels

Haiss, George, Mfg. Co., Inc.
Division of Pettibone Mulliken Corp.
5720 Empire State Bldg., New York 1, N. Y.
Bucket Loaders, Buckets, Portable and Stationary Conveyors, Car Unloaders

Harnischfeger Corp.
4400 West National Ave., Milwaukee 46, Wis.
A Complete Line of Power Excavating Equipment, Overhead Cranes, Hoists, Welders, Electrodes, Motors and Generators, Diesel Engines

HarriSteel Products Co.
420 Lexington Ave., New York 17, N. Y.
Woven Wire Screen Cloth

Hayward Co.
50 Church St., New York 7, N. Y.
Orange Peel Buckets, Clam Shell Buckets, Electric Motor Buckets, Automatic Take-up Reels

Heidenreich, E. Lee, Jr.
Consulting Engineers
75 Second St., Newburgh, N. Y.
Plant Layout, Design, Supervision; Open Pit Quarry Surveys; Appraisals — Plant and Property

Hendrick Mfg. Co.
Carbondale, Pa.
Perforated Metal Screens, Perforated Plates for Vibrating, Shaking, and Revolving Screens; Elevator Buckets; Test Screens; Wedge Slot Screens; Wedge Wire Screens; Open Steel Floor Grating

Hercules Powder Co.
Wilmington 99, Del.
Explosives and Blasting Supplies

Hetherington & Berner Inc.
701-745 Kentucky Ave., Indianapolis 7, Ind.
Asphalt Paving Machinery, Sand and Stone Dryers

Hewitt-Robins Incorporated
666 Glenbrook Road, Stamford, Conn.
Belt Conveyors (Belting and Machinery); Belt and Bucket Elevators; Car Shakeouts; Feeders; Industrial Hose; Screen Cloth; Sectional Conveyors; Skip Hoists; Stackers; Transmission Belting; Vibrating Conveyors, Feeders, and Screens; Design and Construction of Complete Plants; Molded Rubber Goods; Sheet Packing; Transmission Belting; Dewaterizers; Wire Conveyor Belts; Speed Reducers; Gears; Pulleys; Sheaves; Couplings

Hoyt Wire Cloth Co.
Abraso St., off Manheim Pike, Lancaster, Pa.
Aggregate Wire Screens Made of Supertough and Abraso Wire—Smoothtop, Longslot, Oblong Space, and Double Crimp Construction —For All Makes of Vibrators

Hughes Tool Co.
P. O. Box 2539, Houston 1, Texas
Bits—Rock

Manufacturers Division – National Crushed Stone Association
(continued)

Illinois Powder Mfg. Co.
506 Olive St., St. Louis 1, Mo.
Gold Medal Explosives

Independent Explosives Co.
455 Leader Bldg., Cleveland 14, Ohio
Commercial High Explosives

Ingersoll-Rand Co.
11 Broadway, New York 4, N. Y.
Rock Drills, Paving Breakers, Paving Breaker Accessories, Quarrymaster Drills, Drillmasters, Carset Bits, Jackbits, Bit Reconditioning Equipment, Portable and Stationary Air Compressors, Air Hoists, Slusher Hoists, Pneumatic Tools, Centrifugal Pumps, Diesel and Gas Engines

Insley Manufacturing Corp.
801 North Olney St., Indianapolis 6, Ind.
Concrete Carts and Buckets; 1/2 to 2 Cu. Yd. Cranes and Shovels—5 to 35 Tons Capacity, Rubber or Crawler Mounting

International Harvester Co.
Industrial Power Division
P. O. Box 270, Melrose Park, Ill.
Tractors (Crawlers) and Equipment

Iowa Manufacturing Co.
916 16th St., N.E., Cedar Rapids, Iowa
Rock and Gravel Crushing, Screening, Conveying and Washing Plants, Asphalt Plants, Stabilizer Plants, Impact Breakers, Screens, Elevators, Conveyors, Portable and Stationary Equipment, Hammermills, Bins

Jaeger Machine Co.
550 West Spring St., Columbus 16, Ohio
Portable and Stationary Air Compressors, Self-Priming Pumps, Truck Mixers, Concrete Mixers, Road Paving Machinery, Hoists and Towers; Rubber-Tired, Front End Loaders

Jeffrey Manufacturing Co.
East First Ave., Columbus 16, Ohio
Elevator Buckets; Car Pullers; Chains; Conveyors: Belt, Drag, Apron, Vibrating; Idlers; Crushers; Pulverizers; Elevators; Feeders; Pillow Blocks; Stationary Plants; Screens

Johnson-March Corp.
1724 Chestnut St., Philadelphia 3, Pa.
Dust Control Engineers, Wet and Dry Dust Collection Systems, Gas Scrubbers

Joy Manufacturing Co.
333 Henry W. Oliver Bldg., Pittsburgh 22, Pa.
Drills: Blast-Hole, Wagon, Rock, and Core; Air Compressors: Portable, Stationary, and Semi-Portable; Aftercoolers; Portable Blowers; Carpullers; Hoists; Multi-Purpose and Portable Rock Loaders; Air Motors; Trench Diggers; Belt Conveyors; "Spaders"; "String-a-Lite" (Safety-Lighting-Cable); Backfill Tampers; Drill Bits: Rock and Core

Kennedy-Van Saun Mfg. & Eng. Corp.
2 Park Ave., New York 16, N. Y.
Crushing, Screening, Washing, Conveying, Elevating, Grinding, Complete Cement Plants, Complete Lime Plants, Complete Lightweight Aggregate Plants, Synchronous Motors, Air Activated Containers for Transportation of Pulverized Material, Cement Pumps, and Power Plant Equipment

Kensington Steel Co.
505 Kensington Ave., Chicago 28, Ill.
Oro Alloy and Manganese Steel Castings: For Shovels—Dipper Teeth, Crawler Treads, Rollers, Sprockets; For Crushers—Jaw Plates, Concaves, Mantles, Bowl Liners; For Pulverizers—Hammers, Grate Bars and Liners; For Elevators and Conveyors—Chain, Sprockets, Buckets; For Tractors—Rail Links and Grouser Plates; Drag Line Chain

King Powder Co., Inc.
Cincinnati, Ohio
Detonite, Dynamites, and Blasting Supplies

Koehring Co.
3026 West Concordia Ave., Milwaukee 16, Wis.
Excavating, Hauling, and Concrete Equipment

Linde Air Products Co., Division of Union Carbide and Carbon Corp.
30 East 42nd St., New York 17, N. Y.
Oxygen, Acetylene, Welding and Jet Piercing Equipment and Supplies

Link-Belt Co.
300 West Pershing Road, Chicago 9, Ill.
Complete Stone Preparation Plants; Conveyors, Elevators, Screens, Washing Equipment, Speed-O-Matic Shovels—Cranes—Draglines and Power Transmission Equipment

Link-Belt Speeder Corp.
1201 Sixth St., S. W., Cedar Rapids, Iowa
Complete Line of Power Hydraulically Controlled Cranes, Shovels, Hoes, Draglines, Clamshells, 1/2 to 3 Yd. Capacities. Available on Crawler Base or Rubber Tire Mounting

Lippmann Engineering Works
4603 W. Mitchell St., Milwaukee 14, Wis.
Primary and Secondary Rock Crushers and Auxiliary Equipment such as Feeders, Screens, Conveyors, Etc., Portable and Stationary Crushing and Washing Plants

Ludlow-Saylor Wire Cloth Co.
634 South Newstead Ave., St. Louis 10, Mo.
Woven Wire Screens and Wire Cloth of Super-Loy, Steel, and All Other Commercial Alloys and Metals

Manufacturers Division – National Crushed Stone Association
(continued)

Mack Motor Truck Corp.
350 Fifth Ave., New York 1, N. Y.
On- and Off-Highway Trucks, Tractor-Trailers, Six-Wheelers, from 5 to 30 Tons Capacity, Both Gasoline- and Diesel-Powered

Marion Power Shovel Co.
Marion, Ohio
Power Shovels, Draglines, Cranes, Truck Cranes, Mobil Cranes—From 1/2 to 60 Yd.

McLanahan & Stone Corp.
252 Wall St., Hollidaysburg, Pa.
Complete Pit, Mine, and Quarry Equipment—Crushers, Washers, Screens, Feeders, Etc.

Murphy Diesel Co.
5317 West Burnham St., Milwaukee 14, Wis.
Engines—Industrial Engine, and Power Units for Operation on Diesel and Dual Fuel Engines. Generator Sets, AC and DC from 64 Kw. to 165 Kw. Mech-Elec Unit—Combination Mechanical and Electric Power Furnished Simultaneously

National Container Corp. of Ohio
Multi-Wall Paper Bag Division
Jaite, Ohio
Multi-wall Paper Bags, Sewn and Pasted Style for Packaging Lime, Cement, Plaster, Etc.

New York Rubber Corp.
100 Park Ave., New York 17, N. Y.
Conveyor Belting: Stonore, Dependable, and Cameo Grades; Transmission Belting: Silver Duck Duroflex, Soft Duck Rugged, Commercial Grade Tractor

Nordberg Mfg. Co.
Milwaukee 1, Wis.
Symons Cone Crushers, and Symons Gyratory and Impact Crushers; Gyradisc Crushers; Grinding Mills; Stone Plant and Cement Mill Machinery; Vibrating Screens and Grizzlies; Diesel Engines and Diesel Driven Generator Units; Mine Hoists; Track Maintenance Machinery

Northern Blower Co.
6409 Barberton Ave., Cleveland 2, Ohio
Dust Collecting Systems, Fans—Exhaust and Blower

Northwest Engineering Co.
135 South LaSalle St., Chicago 3, Ill.
Shovels, Cranes, Draglines, Pullshovels—Crawler and Truck Mounted

Pennsylvania Crusher Division
Bath Iron Works Corp.
323 South Matlack St., West Chester, Pa.
Single Roll Crushers, Impactors, Reversible Hammermills, Ring Type Granulators, Kue-Ken Jaw Crushers, Kue-Ken Gyratories, Non-Clog and Standard One-Way Hammermills

Pettibone Mulliken Corp.
4710 West Division St., Chicago 51, Ill.
Material Handling Buckets, Clamshells, Draglines, Pullshovels, Dippers, Shovel Dippers, Pumps, Front End Loaders, Bucket Conveyor Loaders, Fork and Bucket Loaders, Speed Swing Loaders, Speed Swing Yard Cranes, Motor Graders, Manganese Steel Castings

Pioneer Engineering Works, Inc.
1515 Central Ave., N.E., Minneapolis 13, Minn.
Jaw Crushers, Roll Crushers (Twin and Tripple), Impact Crushers, Vibrating and Revolving Screens, Feeders (Reciprocating, Apron, and Pioneer Oro Manganese Steel), Belt Conveyors, Idlers, Accessories and Trucks, Portable and Stationary Crushing and Screening Plants, Washing Plants, Mining Equipment, Cement and Lime Equipment, Asphalt Plants, Mixers, Dryers and Pavers

Pit and Quarry Publications, Inc.
431 South Dearborn St., Chicago 5, Ill.
Pit and Quarry, Pit and Quarry Handbook, Pit and Quarry Directory, Concrete Manufacturer, Concrete Industries Yearbook

Productive Equipment Corp.
2926 West Lake St., Chicago 12, Ill.
Vibrating Screens

Quaker Rubber Corp.
Division of H. K. Porter Co., Inc., of Pittsburgh
Tacony and Comly Sts., Philadelphia 24, Pa.
Conveyor Belts, Hose, and Packings

Radio Corporation of America
Inspection and Control Section
Front and Cooper Sts., Bldg. 15-1
Camden 2, N. J.
Tramp Metal Detectors

Rock Products and Concrete Products
79 West Monroe St., Chicago 3, Ill.

Rogers Iron Works Co.
11th & Pearl Sts., Joplin, Mo.
Jaw Crushers, Roll Crushers, Hammermills, Vibrating Screens, Revolving Screens and Scrubbers, Apron Feeders, Reciprocating Feeders, Roll Grizzlys, Conveyors, Elevators, Portable and Stationary Crushing and Screening Plants, Mine Hoists, Drill Jumbos and Underground Loaders

Screen Equipment Co., Inc.
1754 Walden Ave., Buffalo 25, N. Y.
Seco Vibrating Screens; Scales—Industrial, Aggregates, Truck

Simplicity Engineering Co.
Durand, Mich.
Simplicity Gyrating Screens, Horizontal Screens, Simpli-Flo Screens, Tray Type Screens, Heavy Duty Scalpers, D'Watering Wheels, D'Centegrators, Vibrating Feeders, Vibrating Pan Conveyors, Car Shake-Outs, Woven Wire Screen Cloth, Grizzly Feeders

Manufacturers Division – National Crushed Stone Association
(concluded)

SKF Industries, Inc.
Front St. and Erie Ave.,
P. O. Box 6731, Philadelphia 32, Pa.
Anti-Friction Bearings—Self-Aligning Ball, Single Row Deep Groove Ball, Angular Contact Ball, Double Row Deep Groove Ball, Spherical Roller, Cylindrical Roller, Ball Thrust, Spherical Roller Thrust; Tapered Roller Bearings; Pillow Block and Flanged Housings—Ball and Roller

Smith Engineering Works
532 East Capitol Drive, Milwaukee 12, Wis.
Gyratory, Gyrasphere, Jaw and Roll Crushers, Vibrating and Rotary Screens, Gravel Washing and Sand Settling Equipment, Elevators and Conveyors, Feeders, Bin Gates, and Portable Crushing and Screening Plants

Stedman Foundry & Machine Co., Inc.
Aurora, Ind.
Stedman Impact-Type Selective Reduction Crushers, 2-Stage Swing Hammer Limestone Pulverizers, Multi-Cage Limestone Pulverizers, Vibrating Screens

Stephens-Adamson Mfg. Co.
Aurora, Ill.
Belt Conveyors, Elevators, Feeders, Car Pullers, Screens, Skip Hoists, Complete Plants

Taylor-Wharton Iron & Steel Co.
High Bridge, N. J.
Manganese and Other Special Alloy Steel and Iron Castings; Dipper Teeth, Fronts and Lips; Crawler Treads; Jaw and Cheek Plates; Mantles and Concaves; Pulverizer Hammers and Liners; Asphalt Mixer Liners and Tips; Manganese Nickel Steel Welding Rod and Plate; Elevator, Conveyor and Dredge Buckets

Thew Shovel Co.
East 28th St. and Fulton Rd., Lorain, Ohio
"Lorain" Power Shovels, Cranes, Draglines, Clamshells, Hoes, Scoop Shovels on Crawlers and Rubber-Tire Mountings. Diesel, Electric, and Gasoline, 3/8 to 2-1/2 Yd. Capacities

Thor Power Tool Co.
175 North State St., Aurora, Ill.
Thor Power Tools, Wagon Drills, Rock Drills, Sump Pumps

Torrington Co.
Bantam Bearings Division
3702 West Sample St., South Bend 21, Ind.
Anti-Friction Bearings; Self-Aligning Spherical, Tapered, Cylindrical, and Needle Roller; Roller Thrust; Ball Bearings

Travel Drill Co.
P. O. Box 1124, Raleigh, N. C.
"Travel Drill"—Mobile Drill for Secondary Drilling in Quarries and Open Pit Work

Traylor Engineering & Mfg. Co.
Allentown, Pa.
Stone Crushing, Gravel, Lime, and Cement Machinery

Trojan Powder Co.
17 North Seventh St., Allentown, Pa.
Explosives and Blasting Supplies

Tyler, W. S., Co.
3615 Superior Ave., N.E., Cleveland 14, Ohio
Woven Wire Screens; Ty-Rock, Tyler-Niagara and Ty-Rocket (Mechanically Vibrated) Screens; Hum-mer Electric Screens; Ro-Tap Testing Sieve Shakers, Tyler Standard Screen Scale Sieves, U. S. Sieve Series

Universal Engineering Corp.
625 C Ave., N.W., Cedar Rapids, Iowa
Jaw Crushers, Roll Crushers, TwinDual Roll Crushers, Hammermills, Impact Breakers, Pulverizers, Bins, Conveyors, Feeders, Screens, Scrubbers. Bulldog Non-Clog Moving Breaker Plate and Stationary Breaker Plate Hammermills, Center Feed Hammermills. A Complete Line of Stationary and Portable Crushing, Screening, Washing, and Loading Equipment for Rock, Gravel, Sand, and Ore. Aglime Plants. Asphalt Plants

Vibration Measurement Engineers
7665 Sheridan Road, Chicago 26, Ill.
Seismographic and Airblast Measurements, Seismological Engineering, Blasting Complaint Investigations, Expert Testimony in Blasting Litigation; Nation-wide Coverage

Werco Steel Co.
2151 East 83rd St., Chicago 17, Ill.
Castings—Manganese, Alloy Steel; Screen Plates—Perforated Steel Screen Sections and Decks; Buckets; Chains; Belt Conveyors, Idlers; Dipper—Shovel; Drop Balls; Wire Cloth; Wire Rope and Related Products

White Motor Co.
842 East 79th St., Cleveland 1, Ohio
On- and Off-Highway Trucks and Tractors—Gasoline- and Diesel-Powered; Industrial Engines, Power Units, Axles, Special Machine Assemblies; All Classes of Service

Wickwire Spencer Steel Division
Colorado Fuel and Iron Corp.
575 Madison Ave., New York 22, N. Y.
Wire Rope, Vibrating and Space Screens

Williams Patent Crusher & Pulverizer Co.
2701-2723 North Broadway, St. Louis 6, Mo.
Hammer Mills, Crushers, Pulverizers, Roller Mills, Reversible Impactors, and Vibrating Screens